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**Forest
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General
Technical
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WO-28

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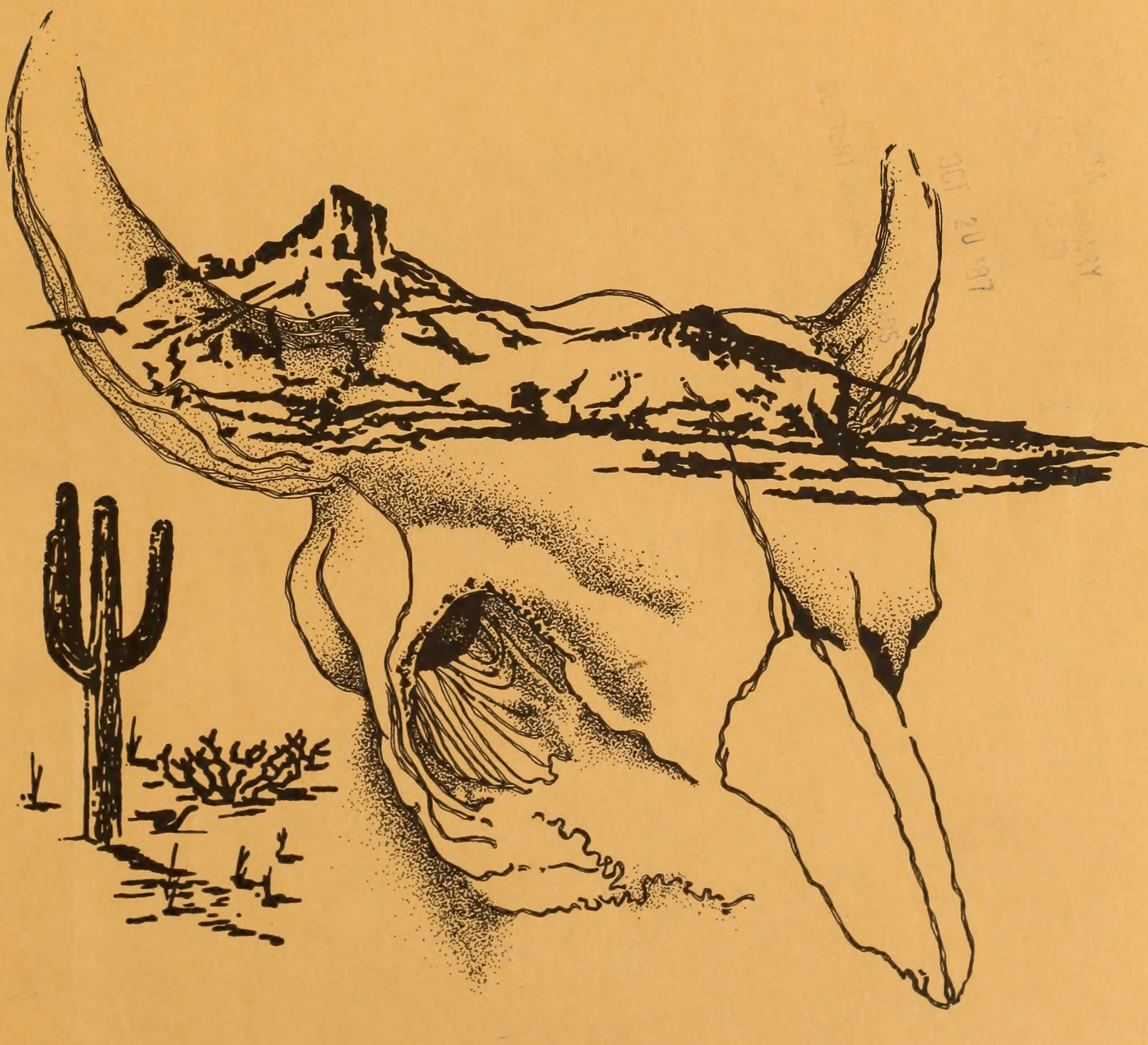
Arid Land Resource Inventories:

Developing Cost-Efficient Methods

An International Workshop
November 30-December 6, 1980
La Paz, Mexico



Lund, H. Gyde, Miguel Caballero, R. H. Hamre, Richard S. Driscoll, and William Bonner, technical coordinators, 1981. Arid land resource inventories: Developing cost-efficient methods (Proc. of the workshop, La Paz, Mexico, Nov. 30-Dec. 6, 1980) USDA Forest Serv. Gen. Tech. Rep. WO-28, 620 p. Wash., D.C.

Proceedings of the workshop, sponsored by Mexican, American, and international organizations, include 107 papers in either English or Spanish with summaries in the alternate language. Topics include: information needs, inventory procedures, inventory planning, land classification, economical mapping and remote sensing systems, cost-efficient sampling schemes, efficient resource measuring techniques, resource data analysis systems, research proposals, and descriptions of the Todos Santos Experimental Forest.

Patrocinado por:

Sponsored by:
International Union of Forestry Research Organizations
Society of American Foresters
Subsecretaria Forestal y de la Fauna, México
Asociación Mexicana de Profesionales Forestales
U. S. Department of Agriculture, Forest Service
U. S. Department of Interior, Bureau of Land
Management.

United States
Department of
Agriculture

**Forest
Service**

General
Technical
Report
WO-28

June 1981

Arid Land Resource Inventories:

Developing Cost-Efficient Methods

Inventarios De Recursos De Tierras Aridas:

Desarrollo De Metodos Eficientes En Costos

An International Workshop
November 30-December 6, 1980
La Paz, Mexico

Technical Coordinators:
H. Gyde Lund
Miguel Caballero
R.H. Hamre
Richard S. Driscoll
William Bonner

Preface Prefacio

This workshop was conceived at the IUFRO Symposium on National Forest Inventories in Bucharest, Romania in June 1978.

Avelino Villa Salas and Miguel Caballero Deloya were interested in hosting an international workshop in Mexico. Gyde Lund, the Chairman of the Society of American Foresters' Inventory Working Group, offered to co-sponsor a meeting if a topic of mutual and international interest and concern could be developed.

The arid lands of the world have frequently been considered wasteland. However, these lands contain many values including unique scenery, wildlife populations, herbage, shrubs and trees, and are also the home of many of the world's people.

In recent years, demands on arid lands have been increasing for recreation, rural and urban development, archeological searching, domestic livestock grazing, agriculture, and wood products. To insure protection and proper management of amenity and non-amenity values, inventories of the basic attributes of arid lands are required. The relatively low economic values of the lands and their remoteness make inventory design a challenge.

Arid lands are common both to Mexico and the United States, and rapidly spreading desertification of these dry regions is an international problem. Consequently, a workshop on developing cost-efficient methods of inventorying the resources of the lands was mutually agreed upon.

Sponsors were lined up and a Program Committee consisting of Miguel Caballero, Gyde Lund, Dick Driscoll, and Bill Pulford was formed. Because of a change in jobs, Bill Pulford was replaced by Bill Bonner.

The committee developed the skeleton for the workshop. Invited speakers suggested by the committee, the sponsors, the moderators, and session chairmen provided muscle. Contributed papers filled in gaps and provided the needed flesh. Papers were screened, more for concepts applicable to arid lands than solely for content, and should be read in the same light. Papers are either in Spanish or English, and have a summary in the alternate language.

Logistical support services committees were organized by the Mexican sponsors. The location and the field trip provided an excellent backdrop for the meeting.

The workshop attracted over 200 participants from 16 countries. Requests for the proceedings have already come from throughout the world. The Arid Land Resource Inventories Workshop was a very timely meeting on a subject of deep international interest and concern.

Workshop Executive Committee

Acknowledgements

The Arid Land Resource Inventories Workshop was the product of close cooperation between conservation agencies and private organizations. They were exceedingly generous in permitting their representatives to attend the many planning meetings, and many of them, as listed below, contributed financially to the support of the workshop or publication of the brochures, programs, and proceedings.

Special credit is due to Miguel Caballero Deloya and Jose Maria de la Puente of the Subsecretaria Forestal y de la Fauna, Mexico, William J. Pulford and William G. Bonner of the USDI Bureau of Land Managemnt, and Richard S. Driscoll of the USDA Forest Service, who spent numerous hours over the past two years planning, promoting, and implementing the workshop.

The Asociación Mexicana de Profesionales Forestales, the International Union of Forestry Research Organizations' Subject Group on Forest Resource Inventories, and the Society of American Foresters' Inventory Working Group provided suggestions for the program format, content, and speakers. They also carried announcements of the workshop in their various newsletters and journals.

Thanks are due also to the session chairmen and panel moderators who shaped and coordinated the program within their areas.

We thank the USDA Forest Service Washington Office for agreeing to finance publication and distribution of the proceedings, and R. H. Hamre of the Rocky Mountain Forest and Range Experiment Station for contributing his editorial expertise and coordinating this effort. The authors have earned our thanks for submitting their camera-ready manuscripts to expedite publication of these proceedings. Each contributor is responsible for the accuracy and style of his or her paper. Statements of contributors may not necessarily reflect the policies of the sponsoring organizations and agencies.

The USDI Bureau of Land Managment was primarily responsible for the advertisement and promotion of the workshop through the publication and mailing of brochures and through announcements in the Resources Evaluation Newsletter.

The Subsecretaria Forestal y de la Fauna, Mexico through its representatives, Heriberto Parra Hake and Armida Hernandez Orihuela, financed and handled graciously and effectively innumerable details concerned with the conduct of the workshop itself, the excellent field trip, tours, evening activities, transportation, registration, and the general welfare of the participants.

Agradecimientos

Our sincere thanks to all the participants who made the workshop a success.

Lastly, and most of all, our thanks to the people of Mexico for being the outstanding hosts for this meeting.

H. Gyde Lund
Oscar Cedeño Sánchez
General Coordinators

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Session Chairmen:

Characteristics of Arid Lands
Harold F. Heady

Arid Land Inventory Challenges
Raúl Villareal Cantón

Meeting the Inventory Challenges
José María de la Puente E.

Proposals for Exchanging Research
Manuel Enríquez Quintana

The Field Trip
Heriberto Parra Hake

Panel Moderators:

Information Needs
Louis O. House IV

Inventory Problems
Paul Schmid-Haas

Inventory Planning
H. Gyde Lund

Land Classification Systems
Richard S. Driscoll

Economical Mapping and Remote Sensing Systems
James R. Getter

Cost Efficient Sampling Schemes
Warren E. Frayer

Efficient Resource Measurement Techniques
David R. Bower

Resource Data Analysis Systems
James C. Space

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Richard S. Driscoll
William G. Bonner
Robert H. Hamre - Coordinator

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Arid Land Resource Inventories:

A Summary of the Workshop[1]

H. GYDE LUND, OSCAR CEDEÑO SANCHEZ,
PAUL SCHMID-HAAS AND JOSE MARIA de la PUENTE[2]

The arid lands and their resources are internationally significant for the people they support and the resources they produce. The purpose of this workshop was to explore cost-efficient methods to inventory and monitor these arid land resources.

The Arid Lands

We started the workshop by listing the characteristics of the arid lands and their uses. One-third of the world's land is arid. Twelve percent of the total land area is hot desert. The lands are generally fragile, and the resource demands are high and growing. In addition to being home to many people, they support wildlife and livestock; produce forage, fiber, wood, fuels, oils, water, and minerals; and provide recreation opportunities.

The Challenges

The challenges for managers of these lands are to meet the increasing demands without undue resource deterioration, and to restore lands already damaged. Deterioration of the vegetation is an irreversible process in some parts of the earth, particularly the arid regions. Very few countries have an adequate inventory system to detect and monitor this deterioration. An important objective of this workshop, therefore, was to present efficient inventory methods for this chore. The problems include defining needed information, and identifying inventory and monitoring techniques.

The information needs are similar to those required for other regions of the world. They include biological information on animals and vegetation; measures of competition, soils, mineral, and climatic data; and attitudes of land owners and users.

The difference from other regions, however, is that data collection is often delayed because of high costs in relation to returns. From a strictly economic perspective, the cost of collecting the data may exceed the foreseeable economic returns from the resources. The accessibility, difficulty of measurements, and requirements for national and perhaps international cooperation further complicate the inventory problem.

The Solutions

Potential solutions to the inventory problems involve inventory planning, classification, mapping, remote sensing, sample design, resource measurement, and analytical techniques. These topics were discussed in the following panels and through the poster session.

Inventory planning can determine the success or failure of a project. Techniques for setting objectives and determining costs and time requirements were presented by the planning panel. In addition, panel members discussed the use of planning modeling techniques, and gave examples of ongoing inventories.

The classification panel discussed uniform ways to group lands and resources. The panelists presented ways to: identify areas having the greatest potential for economic development, identify relict areas, and classify water. A national classification system was discussed, and the use of remote sensing to link classification and mapping was introduced. Ecologically based systems were the most popular and promising.

The panel on remote sensing and mapping presented principles, with examples, to reduce the cost of data collection and increase the utility of the resulting products. Uses of conventional aerial photography and the more exotic sensors for future development of classification and inventory systems were discussed.

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[1] Summary presented at the Arid Land Resource Inventories Workshop, (La Paz, Mexico, November 30-December 6, 1980).

[2] H. Gyde Lund is Project Leader, National Resource Inventory Techniques, USDA Forest Service, USA. Oscar Cedeño Sanchez is Director General del Instituto Nacional de Investigaciones Forestales, Mexico. Paul Schmid-Haas is Forest Resource Inventories Subject Group Leader, International Union of Forestry Research Organizations, Switzerland. Jose Maria de la Puente is Director General del Inventario Nacional Forestal, Mexico.

Sampling schemes utilizing remote sensing, and the use of remote sensing for monitoring and providing economical area estimates were illustrated.

Sampling designs to produce low-cost yet objective and reliable information were presented on the next panel. Designs using field techniques alone, remote sensing alone, and combinations of the two were given for determining recreational opportunities, animal numbers, vegetation condition, soil condition, and multiresource data. Point sampling for shrubs and trees was introduced. Designs capitalizing on the reliability and low cost of remote sensing, calibrated with field samples, appeared to be the most promising. Designs utilizing digital displays of remotely sensed data are also growing in popularity. They have the potential of linking the local situation with broader information needs, and of monitoring resource changes.

The resource measurements panel concentrated on direct and indirect methods of quantifying soil salinity, animal populations, vegetation variables (including volume, growth, and phytomass), utilization, stocking, community structure, and gum production. Some new concepts of plot designs and instrumentation were also presented.

The final panel covered compilation, analysis, reporting, and information management systems. Newly introduced equipment, such as portable data recorders and remote terminals, speeds processing, eliminates errors, and reduces overall inventory costs. Systems and procedures for analyzing inventory data, including construction of volume tables and growth and yield equations, and summarizing and manipulating information, were given. Models and simulation techniques to evaluate trade-offs between wildlife, livestock, and hydrologic resources were presented as techniques that exist today. Model development is an economically justifiable method of translating research results without conducting extensive, costly studies.

The location of the workshop and the field trip gave us further insight into the arid land resources, uses, information needs, and inventory problems, and introduced techniques to solve some of these problems.

Research Needs

The final session focused on where we go from here. The panel started with a presentation showing how inventory information coupled with modern technology has solved a water problem in Tunisia. Another paper focused on exact inventory problem areas needing additional effort. Other papers highlighted successful research in Mexico. Methods to increase international research participation and cooperation were introduced.

Practical methods to inventory and monitor vegetation dynamics are sorely needed. The enormous and often uncontrolled influence of man on vegetation makes this problem area of utmost importance. In addition, research strategies linking inventory designs to management decisions are also required.

Conclusions

1. Due to the world's uncontrolled population growth, the need to find new sources of commodities, particularly of food, fiber, and fuel becomes urgent.

2. The natural resources of the arid lands offer a partial solution as long as we learn to manage wisely. These lands have been overutilized and abused.

3. For these reasons, it is necessary to have precise estimates of the magnitude and potential of the natural resources. A knowledge of the vegetation, soils, rainfall, and other resources is indispensable.

4. This workshop provided the opportunity to exchange techniques and information among representatives from 16 nations.

5. Those inventory techniques are related to field sampling, remote sensing, and efficient utilization of natural and human resources.

6. Because of differences in inventory objectives and in locations, each technique presented needs to be carefully tested before being accepted as being the most appropriate.

7. One of the most important attainments of this workshop has been the personal contacts among scientists that devote part of their lives to the study of arid lands and inventory techniques. From these a promise of future communications to solve specific problems of the arid regions in different parts of the world has emerged.

The workshop in general, has provided guidance for inventorying arid land resources to establish a firm foundation for their utilization and protection.

As evidenced by the participation in this workshop, arid lands, resources, and people are of international concern. The needs, demands, and problems of inventorying and monitoring natural resources are worldwide. No one nation can any longer stand alone. Thus, these problems may best be solved through international cooperation. This workshop and the resulting proceedings will serve as a blueprint to show nations of the world how they can share their experiences in solving some most difficult problems.

Inventario de Recursos de Tierras Aridas:

Un Resumen de la Reunion

Las zonas áridas y sus recursos adquieren especial significado internacional por las poblaciones que las habitan y por los recursos que producen. El propósito de esta Reunión ha sido el explorar métodos eficientes en costo para el inventario y la detección de cambios de los recursos de tierras áridas.

Las Tierras Aridas

Inciamos la reunión listando las características de las tierras áridas y sus usos. La tercera parte de las tierras del mundo ha sido clasificada como desierto caliente. Los suelos son generalmente muy frágiles y la demanda por los recursos, es amplia y creciente. Además de constituir el hogar de gran parte de la población mundial, las tierras áridas son productoras de fauna silvestre, ganado, forraje, fibras, madera, combustibles, aceites, agua, minerales y oportunidades recreativas. El reto en el manejo de estas tierras consiste en satisfacer la demanda creciente sin deterioro indebido y en restaurar tierras previamente deterioradas. Los retos incluyen la definición de necesidades de información y la identificación de problemas de inventario y de detección de cambios.

Los Retos

Las necesidades de información son muy similares a aquellas que se requieren en otras regiones del mundo. Incluyen información biológica de animales y de vegetación, mediciones de competencia, de suelos, minerales y de datos climáticos, así como de la actitud de los dueños y usuarios del recurso. La diferencia con respecto a otras regiones consiste, sin embargo, en que la colección de los datos se retrasa frecuentemente debido a costos.

Si se analiza desde el ángulo económico, el costo de colectar los datos puede exceder a los beneficios económicos predecibles de los recursos. La accesibilidad, la dificultad de las mediciones y los requerimentos de cooperación nacional y tal vez internacional, complican aún mas el problema del inventario.

La ubicación de la reunión y el recorrido de campo nos proporcionaron mayor compenetración de los recursos de tierras áridas, de sus usos, sus necesidades de información y de los problemas de inventario, presentándonos algunas técnicas para la solución de estos problemas.

Las Soluciones

Las soluciones a los problemas de inventario se ubicaron dentro de la planeación de inventarios, clasificación, mapeo y sensores remotos, diseño de muestreo, medición del recurso y técnicas analíticas. Estas se analizaron en los páneles siguientes al igual que a través de la exhibición de posters.

La planeación del inventario puede conducir al éxito o al fracaso del proyecto. En el pánel de planeación se presentaron técnicas para establecer objetivos y determinar costos, asi como requerimientos de tiempo. Adicionalmente se comentó sobre el empleo de técnicas para la planificación de modelos y se citaron ejemplos de inventarios en ejecución.

El pánel de clasificación discutió procedimientos uniformes para agrupar las tierras y los recursos. Las ponencias presentaron alternativas para identificar áreas que tienen el máximo potencial de desarrollo económico, que identifican relictos y para clasificación de aguas. Se discutió un esquema de clasificación nacional y se presentó el uso de sensores remotos para entrelazar la clasificación y el mapeo. Los sistemas basados en la ecología resultaron ser los mas populares y promisorios.

El pánel sobre sensores remotos y mapeo presentó principios y ejemplos para reducir el costo de recolectar datos con objeto de aumentar la utilidad de la información resultante. El empleo de la fotografía áerea convencional y de los sensores mas exóticos, fueron discutidos. Se ilustraron esquemas de muestreo que utilizan sensores remotos, asi como el empleo de sensores remotos para detección de cambios y para proveer de estimadores económicos de área.

En el siguiente pánel se presentaron diseños de muestreo orientados a producir información de bajo costo, no obstante ser objetiva y confiable. Se dieron diseños que usan únicamente técnicas decampo, que emplean sólamente sensores remotos,

así como combinaciones de los dos para determinar oportunidades recreativas, número de animales, condiciones de vegetación, condición del suelo y recursos múltiples. Se presentó el muestreo puntal para arbustos y árboles. Aquellos diseños que capitalizan la confiabilidad y el bajo costo de los sensores remotos, calibrados con muestreo de campo parecen ser los mas promisorios. Igualmente, los diseños que emplean la capacidad de mapeo de los sensores remotos están creciendo en popularidad, ligando la situación local con necesidades de información mas amplias para detectar cambios del recurso.

El pánel sobre medición del recurso se concentró sobre métodos directos e indirectos, eficientes para cuantificar la salinidad del suelo, poblaciones de animales y variables de la vegetacción, incluyendo volúmen, crecimiento y fitomasa, utilización, densidad, estructura de la comunidad y producción de goma. También se dieron algunos conceptos sobre nuevos diseños de campo e instrumentación.

El pánel final, para confrontar los retos, cubrió la compilación, el análisis, el reporte y la información en los sistemas de manejo. La introducción de nuevo equipo como son las grabadoras portátiles de datos y las terminales remotas aceleran el proceso, eliminan errores y reducen los costos globales del inventario. Se expusieron sistemas y procedimientos para analizar datos de inventario que incluyeron la construcción de tablas de volúmenes, ecuaciones de crecimiento y producción, así como la sumarización y manipulación de información. Se presentaron, como técnicas hoy existentes, modelos y técnicas de simulación para evaluar intercambios entre fauna silvestre, ganado y recursos hidrológicos. Los modelos constituyen un método económicamente justificado de traducir los resultados de la investigación sin necesidad de llevar a cabo estudios extensivos y potencialmente costosos.

Necesidades de Investigación

Este pánel final se enfocó sobre donde necesitamos ir a partir del estado actual. El pánel se inició con una presentación que mostró cómo la información de inventario, acoplada con tecnología moderna, ha resuelto un problema de agua en Túnez. Otra ponencia se orientó a problemas de inventario que requieren de soluciones adicionales. Se discutieron alternativas para aumentar la participación en la investigación y la cooperación entre naciones.

Conclusiones

1. Debido al aumento desmedido de población que se registra en el mundo, resulta imperativa la necesidad de buscar nuevas fuentes de satisfactores, principalmente alimenticios, forestales y energéticos.

2. Las zonas áridas ofrecen una posibilidad de solución, siempre y cuando sepamos manejar adecuadamente sus recursos naturales, los cuales frecuentemente son objeto de abuso, especialmente por lo que se refiere a la vegetación.

3. Por este motivo resalta la necesidad de conocer con grados confiables de precisión, la magnitud de esos recursos naturales, pues además de la vegetación, es indispensable conocer los suelos, la precipitación pluvial, y la fauna silvestre, entre otros,.

4. Esta reunión ha permitido la identificación en los propósitos anteriores entre representantes de 16 Naciones del mundo, que se han reunido en la Ciudad de La Paz, B.C.S.

5. Los procedimientos en donde ha habido mayor intercambio técnico-científico han sido en los aspectos de muestreo de campo, de percepción remota, y de empleo eficiente de los recursos naturales y humanos para el propósito de inventariar lo que las tierras áridas actualmente contienen.

6. Estas técnicas de medición tienen que ser revisadas cuidadosamente antes de aceptarse como las más apropiadas - según la región de que se trate y el tipo de estudios a realizar.

7. Uno de los logros más valiosos de esta reunión, sin duda ha sido el conocimiento personal entre los técnicos que dedican parte de su vida al estudio de las Zonas Aridas, pues de éllo ha resultado la promesa de intercomunicación para resolver problemas específicos de regiones áridas en diferentes regiones.

   Esta Reunión en general, ha aportado valiosos elementos de juicio, para continuar la tarea que el hombre ha emprendido - para conocer los recursos del desierto de una manera veraz y así establecer las normas para su protección y su juicioso aprovechamiento.

Como resultó evidente por la participación en este congreso, el interés por las tierras áridas, sus recursos y sus poblaciones, constituyen una preocupación internacional. Las necesidades, las demandas y los problemas de cuantificación y de detección de cambios en los recursos naturales son mundiales. Ninguna nación puede continuar permaneciendo sóla.

Es razonable señalar que la solución a estos problemas se puede alcanzar óptimamente a través de cooperación internacional. Se espera que este congreso y las memorias que de él derivarán, servirán de constancia respecto a como las naciones del mundo pueden compartir sus experiencias en la solución a uno de los problemas mas importantes.

Seccion I. Características de las Tierras Aridas, sus Recursos y su Uso. - Un Resumen[1]

Section I - Arid Land Characteristics, Resources and Uses - An Overview[1]

Harold F. Heady[2]

Abstract.--This paper attempts to accomplish two purposes. The first is to place before the Workshop two major but difficult questions: One, to what objectives should the arid land inventory be directed? and two, should not a resource inventory be more concerned with monitoring use effects and less with the "state-of-the-system"? My illustrations accomplish the second purpose, to describe the major cold deserts of western North America.

The UN Conference on Desertification defined the arid zone as "lands that support sparse perennial and annual vegetation which in turn support domestic and other grazing animals, but rainfed agriculture is not possible." Extreme deserts are drier, more rainfall leads to thick natural vegetation and forestry or farming as ways of life. This definition is sufficient for us because the Conference is here to study methods of inventory no matter how dry the landscape and the sparseness of vegetation and animals.

Section I, consisting of four papers, is assigned the task of describing arid lands, the primary producers and consumers on them, and the uses made of arid land ecosystems. This paper shows examples from the cold deserts of the western United States. It also addresses a few ecosystem attributes of a resource which is both highly dispersed and subject to highly localized impacts from use. One of my purposes is to place before you a few difficult questions about arid zone inventories.

OBJECTIVES OF AN INVENTORY

The specifications of a resource inventory should begin with a clear description of how the information will be used. For example, it could be for development of national policy, for land-use planning at a state or district level, or for determination of uses and managerial impacts on individual tracts of land. Most resources inventories record soil, water, vegetation, animals, history, constructed facilities, etc. by measurement and distribution (often on maps). The commonly held rationale for resource inventories is that everything out there must be recorded before anything is used, managed or changed.

Now let us look at the basic informational needs for two specific land uses, domestic animals and wild animals. Agencies that charge fees for grazing by domestic animals and manage public lands for wild animals need to determine grazing capacities for each animal of concern. For livestock, the most appropriate parameter to estimate is probably biomass of forage, but not all herbage is forage; therefore the forage population must be defined. Typically, available forage is estimated only once and on a weight basis. For wild ungulates two parameters may be equally important, forage and cover. Each animal species, especially the wild ones, has its own requirements for types of forage and cover. The spectrum of individual requirements may be relatively specific or it may be satisfied with wide ranges of foods and cover. If grazing capacities are to be accurately determined in the resource inventory, precise definitions are needed of the food and cover required by each species. The survey techniques would then be specifically applied to measure those required parameters. My example of one factor for livestock and two for wild ungulates oversimplifies complex interactions of many factors.

Many range scientists, but not all, believe that grazing capacity for any animal cannot be determined by any currently available survey method. Weather variations, seasons of grazing, animal populations, and other variables are too great for a one-time survey to be reliable. It is a bit like measuring average annual precipitation with data from a single year.

The dilemma, then is the choice between stipulating the objectives of the inventory first so that good information about a few of the necessary attri-

[1]Paper presented at an international workshop on Arid Land Resources Inventories: Developing Cost-efficient Methods. La Paz, Mexico, November 30-December 6, 1980.

[2]Harold F. Heady is Professor of Range Management, Univ. of California, Berkeley, CA. 94720.

butes can be obtained at the appropriate scale, or secondly, doing a massive inventory of many attributes that is intended to cover all contingencies. Often the scale of such inventories does not match the needs of management. The most serious aspect of the latter alternative is that managers tend to postpone necessary managerial practices until everything possible is learned about the resources. I hope this conference will help us learn how to strike a balance between these alternatives.

As you might guess my experience leads me to suggest that land managers get on with the job. Here is an example of a successful land rehabilitation program that did not wait for an intensive survey of soil and vegetation. Between 1963 and 1973, special appropriations supported 205,000 ha of Artemisia control, 108,000 ha of seeding, 3,330 km of fencing, 1,600 water developments, and 741 km of pipelines in an area 100 km by 280 km in southeastern Oregon, USA. Livestock management systems formed an integral part of each allotment program from the beginning. Only 8 percent of the total district was treated with brush control and seeding, enough to permit rapid increase in the adjacent native perennial bunchgrass. In 10 years the estimated grazing capacity increased from 285,000 animal unit months to an estimated 438,000 for the whole district.

Values other than for livestock also increased because of the project, or at least none could be found that was damaged. Wild horses, pronghorn antelope and bighorn sheep increased. Other species exhibited varied responses in relation to change in their particular habitat requirements, but none seemed to have a negative response to land treatments. Water for livestock also benefited waterfowl and fisheries. Range restoration, stimulated by the need for food production and made necessary by past land abuses, favorably served many dwellers on this piece of rangeland. Most current damage to soil is caused by off-road vehicles not to grazing with the possible exception of overuse by wild horses.

Most of this rehabilitation program was based upon careful reconnaissance-type analysis by experienced people; not on detailed inventories. Roughly, the sites containing the best 8 to 10 percent of the land were easily delineated in sufficient detail for managerial decision making. Sites to begin rangeland rehabilitation can be selected and treated successfully in many instances before intensive surveys are made, provided that goals and objectives are clearly defined.

MONITORING EFFECTS OF LAND USE

The major challenge in the gathering of resource information is measuring the effects of land use. A one time inventory for determination of arid land resources, no matter how sophisticated, does not measure trends of vegetation and animal populations. That requires at least two visitations and preferably more to the same plots or area. Further precautions must be followed. The several differing types of cyclical change present in all ecosystems must be carefully separated from the effects of management. Mistakes can be made in calling these changes treatment differences.

Vegetation is different from day to day and week to week. For example, filaree (Erodium cicutarium) shortly after germination forms a rosette of leaves that may have high ground cover. At that time annual grasses are tiny. A couple of weeks later the grasses and filaree show signs of maturity and may have near equal ground cover. After another week the grasses remain although they are mature and dry but the filaree is shattered and gone. Let us suppose that it took a week each to inventory four adjacent grazing allotments. The first turned out to be dominated by filaree, the last one sampled was all grass and the other two mixtures of the two. Any of three conclusions that differences were due to vegetational phenology, or to grazing treatment or to both could be right or wrong, but most likely the differences reflect seasonality not degree or kind of use.

Another type of vegetational change is that occurring from one year to the next. Precipitation is erratic in arid areas, both as to timing and amount. In deserts the perennials, mostly shrubs, grow so slowly that they seem to exist with little or no response to above average precipitation, except for abundant flowering. The annual species, being opportunists, hardly appear during drought but they cover the landscape with abundant herbage in wet periods. Inventories taking two or three years to complete, such as those needed for environmental impact statements, can confound this type of vegetational change with other kinds of change -- in other words ascribe vegetational differences to the wrong cause or causes.

Still another type of vegetational change important to land managers is plant succession. Succession is directional, predictable and results in a different more or less permanent vegetation. An example of succession related to land use is the well documented change from climax semidesert grassland to subclimax desert shrub dominated by creosote bush (Larrea divaricata) on the Jornada Experimental Range in southern New Mexico. Similar examples of deterioration occur in the cold deserts as well. Measurement of range improvement in southeastern Oregon is an example that was monitored on a simple but extensive basis. We know what happened. Monitoring of succession is critical in the determination of management effectiveness.

Patterns of vegetation change vary from site to site; so inventory and monitoring must be done on a site basis. Just as important is use of procedures that prevent natural and uncontrollable changes related to (1) day or week in the growing season and (2) differences between years from being labeled deterioration or improvement. True range improvement, sometimes the same as plant succession,

usually results from some controllable human use or imposed managerial practice. It is highly important to make these distinctions but few inventories do it.

GRAZING CAPACITY A FORM OF MONITORING

The modern way to establish or change stocking rate employs monitoring procedures that measure trend in range vegetation. It is based on the rationale that all the land is and has been used by a known stocking pressure. If the vegetation is deteriorating that pressure is too great, adjustments need to be made in the average stocking rate, because the grazing capacity is set at too high a figure. If range improvement is underway the grazing capacity may be underestimated and a different set of corrections may be needed. Determination of change in stocking rates should be an exercise in monitoring not one in inventory. Many other land management decisions in addition to stocking rates are better served by a program of monitoring than by inventory. I hope this conference considers how monitoring should be done as well as inventories.

RESUMEN

Este artículo trata de lograr dos objetivos. El primero consiste en presentar a los participantes en los Talleres dos importantes pero difíciles preguntas: Primero, ¿ hacia qué objetivos debe dirigirse el inventario de tierras áridas? Segundo, ¿ no debería un inventario de recursos poner más énfasis en la supervisión de los efectos del uso de la tierra que en "nivel del sistema"? Mis ejemplos cumplen el segundo propósito: describir los principales desiertos fríos de la parte oeste de Norte América.

Hot Deserts of the World: What and Where[1]

William G. McGinnies[2]

After considering the causes of aridity, desert climates are described, and the location of hot deserts are shown on maps and their characteristics noted desert landforms, soils, vegetation and fauna are briefly discussed.

INTRODUCTION

If I were to limit my discussion strictly to hot deserts according to current classification, I would include only the deserts of northern Africa and eastern Madagascar; the eastern portion of the Arabian peninsula; the coastal rim along the Red Sea, Persian Gulf and Indian Ocean to Pakistan and India; northern Australia, the northern part of the Atacama desert, the very small desert areas in Brazil and the northern part of South America; and the Sonoran Desert in North America.

If I included the warm deserts, I would add the western side of the Arabian peninsula, southern Africa, southern Australia, the central south American desert, and the Mojave and Chihuahuan deserts in North America.

CAUSES OF ARIDITY

Aridity is commonly the result of three situations:

1. Location in the 15° to 30° latitude zone both north and south of the equator.

2. Rain shadow areas where moisture is removed from the prevailing winds by high mountains.

3. Coastal areas adjacent to cool ocean currents.

By far the greatest extent of desert conditions is to be found in the 15° to 30° latitude zones that include high pressure cells, subsiding air; and relative atmospheric stability. The great mass of the northern Africa-southern Asia dry area and the warm deserts of North America, north of the equator; and the Australian deserts south of the equator fall in this category which includes most of the hot deserts of the world.

The Great Basin desert in North America sheltered by mountains from the moisture bearing winds from the Pacific Ocean, the great arid expanse in central and eastern Asia sheltered from the Indian Ocean monsoons by the 4000-meter-high Himalaya Mountains and the Tibetan plateau are examples of rain shadow deserts. Also, the Monte-Patagonia desert area in South America owes its existence to the shelter of the Andes to the west.

Coastal deserts with very low precipitation, but receiving moisture from the cool ocean waters, occur on the west coasts of Africa and South America.

DESERT CLIMATES

There have been various concepts of the term desert with differences in degree rather than in broad characteristics. Some scientists, especially those living in extreme arid areas, believe the term desert should be limited to areas with precipitation of 100 mm or less occurring irregularly and in which there are periods of a year or more without any precipitation. Then there are others who believe the term desert should be applied to areas with precipitation of 250 mm or even 400 mm in hot climates, particularly if the rainfall is seasonal and there is a protracted dry season. A recent UNESCO-MAB publication does not use the term desert but refers to extreme deserts as hyper-arid, and deserts as arid, while retaining the term semi-arid for regions between sub humid and arid.

There have been many approaches to the expression of desert climate on the basis of precipitation, temperature and evaporation. A widely accepted approach is that of Thornthwaite (1948) which is based on the ratio between precipitation and potential evapotranspiration. Thornthwaite used the

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[1]Paper presented at Arid Land Resource Inventories Developing Cost Efficient Methods Workshop, November 30 - December 6, 1980, La Paz, Mexico.
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point where precipitation balances evapotranspiration to separate humid from dry climates, and arbitrarily assigned values 0 to -20 for sub humid -20 to -40 for semiarid, and, below -40 as arid; Meigs (1953) used Thornthwaite's calculations as a base in the preparation of homoclimatic maps of the arid regions of the world, and added additional information to indicate seasonality of precipitation and mean temperatures of the coldest and warmest months. Meigs separated out the extremely arid climates on the basis of low and erratic precipitation with periods of at least 12 months without precipitation.

Based on Meigs' classification, extremely arid climates are found on 4 percent of the world land area, and arid and semiarid are each found on about 15 percent, making a total of 34 percent.

Africa, with nearly 12 million km^2, has the greatest arid area followed by Asia with 9 million km^2, Australia with 4 million, South America with just under 1.4 million and North America with 1.3 million km^2 (Petrov 1976). Africa and Asia combined have about three fourths of the world's deserts, and these extend in almost a continuous line from the Atlantic coast of Africa to the Hwang Ho River (Yellow River) in China. Australia with about 44 percent arid area has more desert area than North and South America combined.

LOCATION OF HOT DESERTS

In 1979 UNESCO published a map of arid regions, based on the maps of Meigs, in which radiation and wind values were added for greater accuracy. This map includes subhumid in addition to semi-arid, arid and hyper-arid zones. By the use of color gradations along with circles to indicate precipitation characteristics, hot, warm, and cool deserts can be distinguished (UNESCO 1979).

Meigs' homoclimatic maps (Meigs 1973) show the climatic characteristics of semiarid and arid areas and a study of his map legend enables one to see not only degrees of dryness but seasonal moisture and temperature characteristics as well. Because of their greater convenience I am using them to identify the hot deserts of the world. Under the Meigs classification hot deserts would have a mean temperature of at least 30°C for the hottest month and warm deserts a mean of 20°C.

Looking at the climate of hot deserts in detail we can start with Northern Africa which includes the Somali-Chalbi desert on the east and the Sahara on the north (fig. 1).

The Somali-Chalbi, located along the shores of the Red Sea and Gulf of Aden while coming under the influence of the intertropical convergence influence, owes its low precipitation largely to orography and coastal upswelling. The temperature is generally hot with little temperature variation from summer to winter as shown by Meigs indicators of 33 and 34. The world's highest yearlong mean temperatures have been recorded in Somaliland.

The Sahara, largest desert in the world with an area of approximately 7 million km^2, extends from the Atlantic Coast to the Red Sea (fig. 1). It is bounded on the north by the Atlas Mountains and the Mediterranean. The southern boundary, which generally follows the 16th parallel, is not well defined as there is a broad transition between the desert and the semi-arid Sahel.

The Sahara includes some of the hottest and driest areas in the world including the highest temperature recorded anywhere 136.4°F in shade at El Azizia, Libya. The coolest portion near the Mediterranean has Meigs values of 14, the hottest on the south 34, with most of the area falling in the 24 category. The Sahara has a Mediterranean climate in the north with winter precipitation, and a tropical climate in the south with scanty rainfall at all times.

The Arabian Desert (fig. 2) includes the nations of the Arabian Peninsula, and Jordan, Iraq, Israel, Syria and a small part of Iran. In the northern half it is arid or extremely arid with scanty precipitation, and scanty precipitation at any time in the year in the southern half. The southern portion given a 34 value is hot with yearlong warm temperatures gradually changing to cooler winters in the north with a rating of 14.

The hot desert climate extends eastward along the southern coast from the Arabian desert to the Thar desert which includes arid portions of west Pakistan and a portion of western India (fig. 2). The Thar, assigned Meigs values of 24, is in a transitional zone between major wind belts with the eastern portion dominated by mid-continent monsoons. Although it has cold winters with a 13 and 14 rating, some may consider the Iranian desert lying north of this coastal belt as a hot desert. Its summer temperatures may be as high as those of deserts to the south and west, its vegetation closely related to that of the Sahara and Thar Desert. It has primarily a Mediterranean type climate with winter precipitation produced by cyclonic storm systems.

North and east of the Iranian desert and extending from the Caspian Sea on the west to the Hwang Ho River (Yellow River) in China is a great arid area with climates ranging from extremely arid to semiarid (fig. 2), but the deserts are considered cold deserts with a general rating of 03 with some as low as 02. The Turkestan desert on the west, including the Kara-Kum and Kyzyl-Kum deserts rated 03 and 14, has a Mediterranean type of rainfall distribution but with colder winters than typical Mediterranean climates. To the east there is a transitional area towards those with no seasonality of precipitation and those with summer precipitation at the lower elevations. Summers are hot but winters are cool to cold. Meigs ratings are mostly 02 and 03 at higher elevations. The winters are cold and the summers cool to warm. While the principal deserts are the Takla-Makan and the Gobi, there are several smaller deserts separated by topographical barriers.

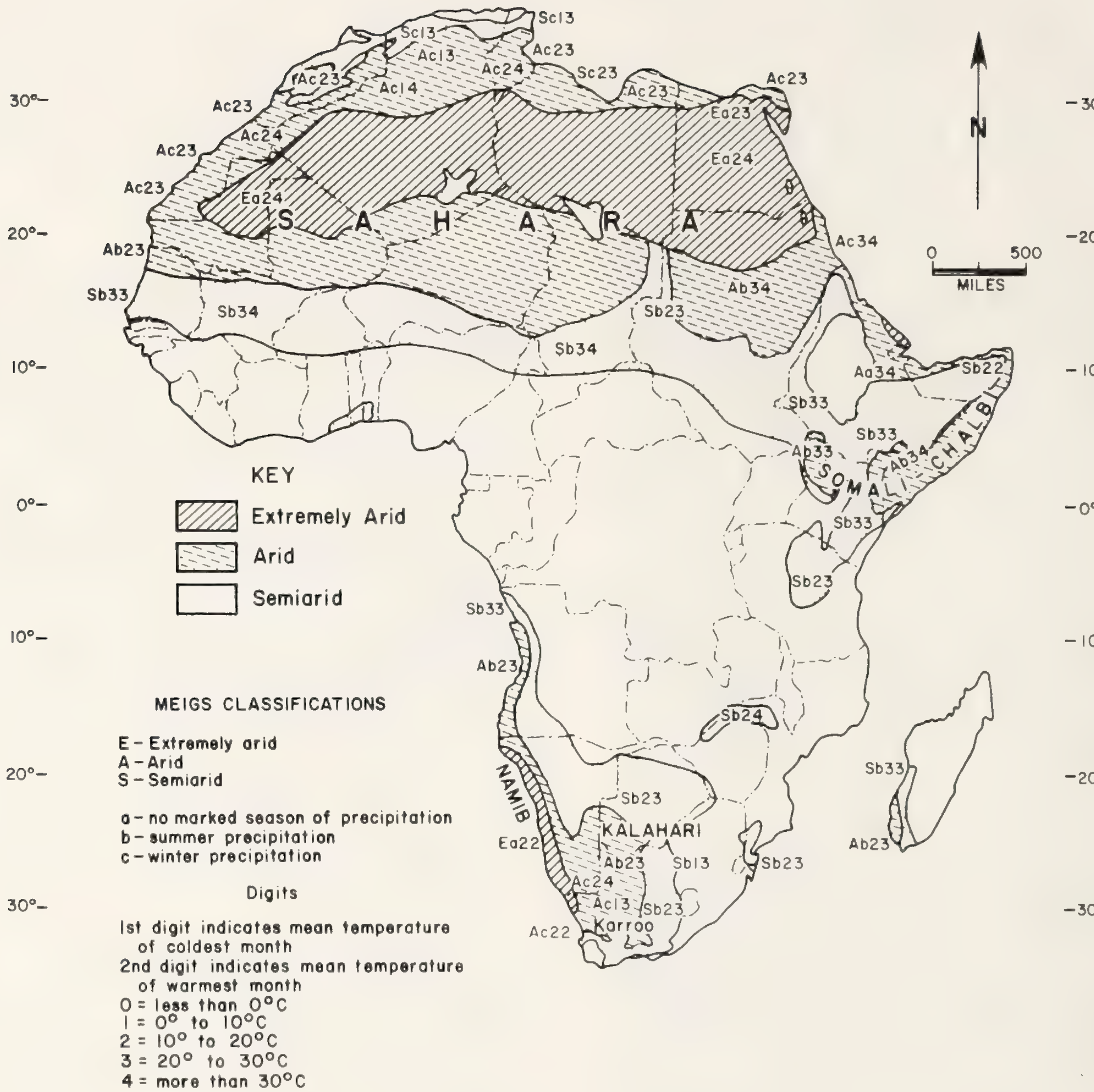

Figure 1. Arid Lands of Africa (after Meigs)

Figure 2. Arid Lands of Asia (after Meigs)

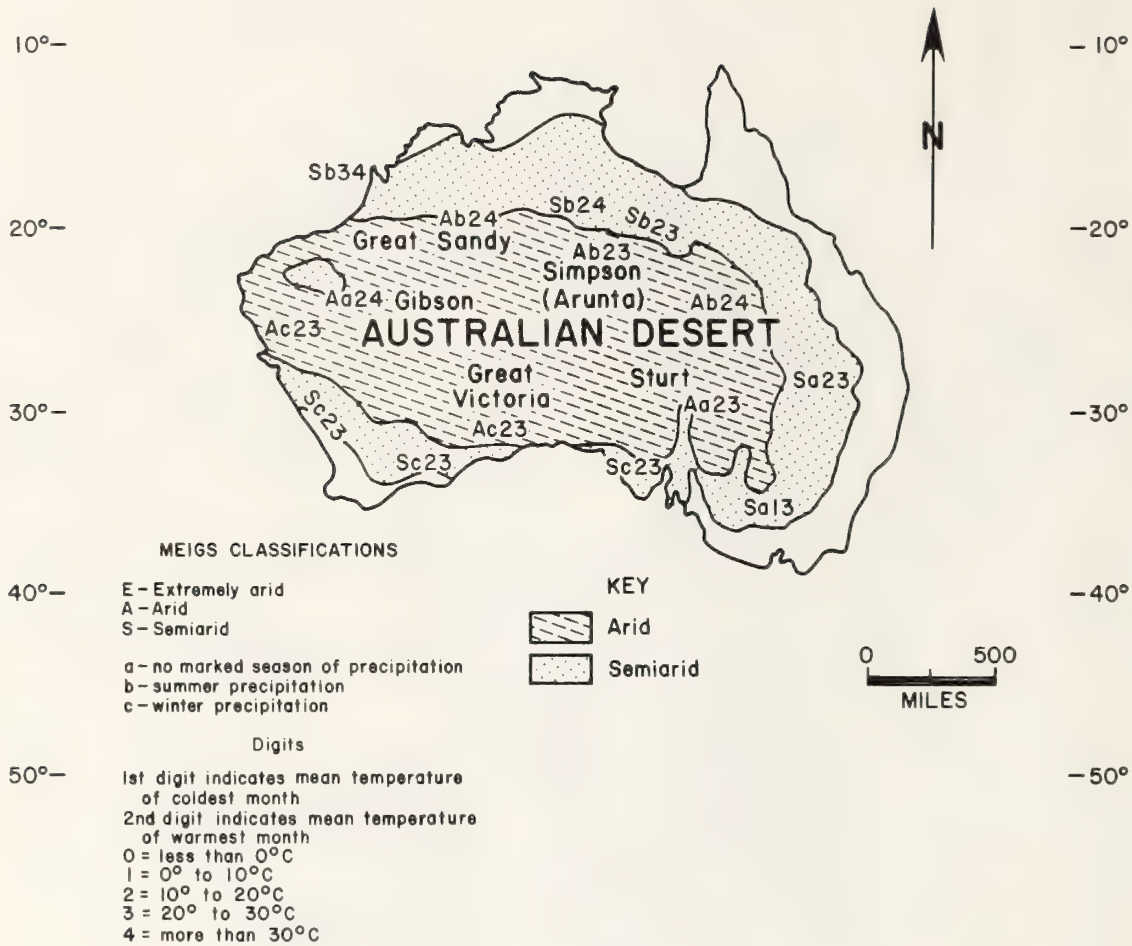

Figure 3. Arid Lands of Australia (after Meigs)

Figure 4. Arid Lands of South America (after Meigs)

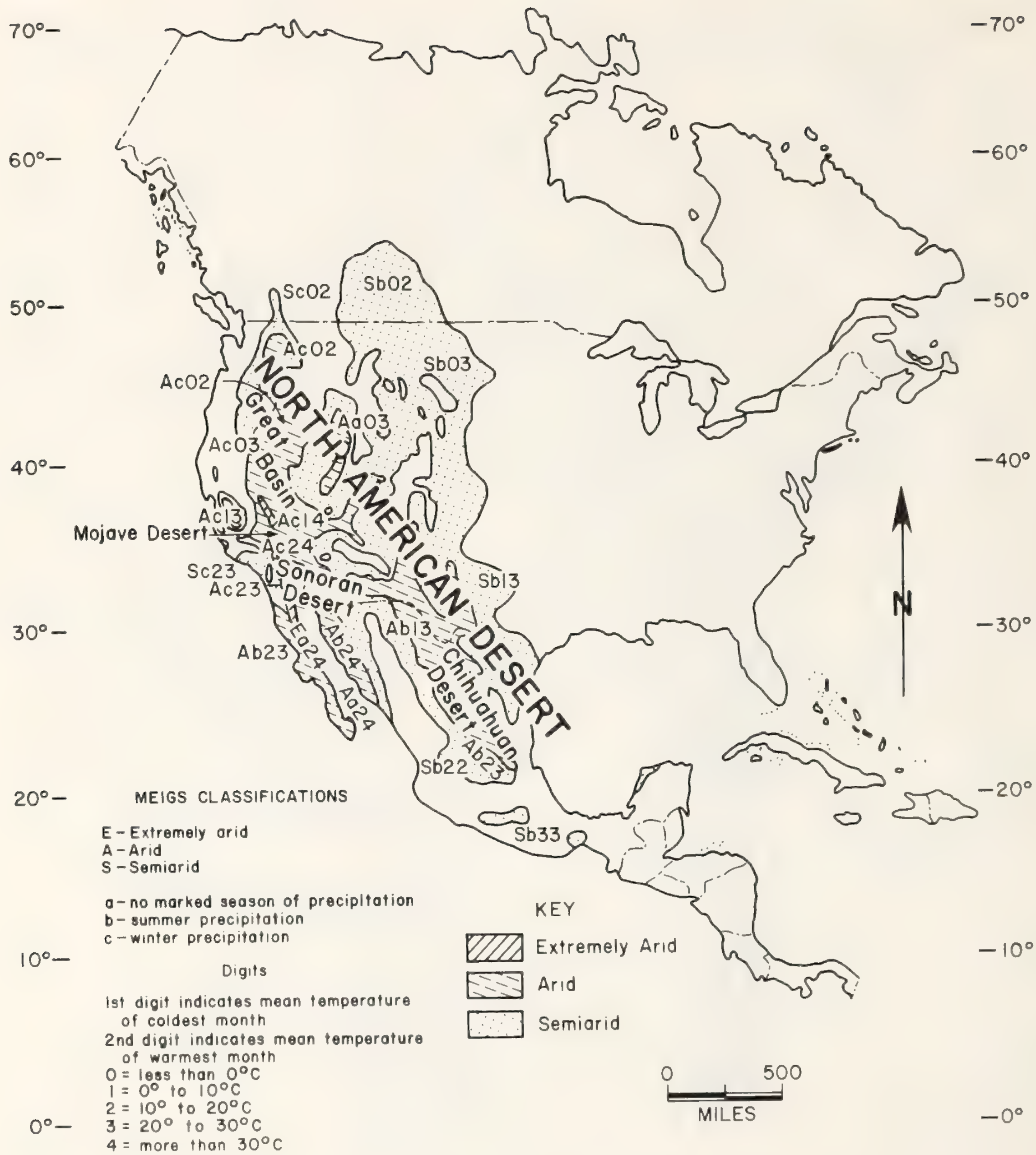

Figure 5. Arid Lands of North America (after Meigs)

The next largest hot desert area is in Australia. While there are no extremely arid areas in Australia (fig. 3), nearly half of the continent is classified as arid, with the northern part considered a hot desert with a general rating of 24 and the southern part a warm-to-hot desert with a rating of 23. The climate is of monsoonal type north of about latitude 20°S. and Mediterranean type south of about latitude 32°S. The intermediate area receives little benefit from either system.

The two coastal desert areas, the Namib-Kalahari in Africa and the Peruvian-Atacama in South America, have some hot-to-warm desert characteristics.

The Namib (fig. 1) classified as a warm desert with a general Meigs rating of 22 varies from extremely arid with less than 50 mm of precipitation, with some benefits from mist and dew, to semiarid, while the Kalahari-Karroo portion has a range of precipitation up to semidesert amounts. The northern end with ratings of 33 qualifies as a hot desert.

Only the northern portion of the Peruvian-Atacama desert area with ratings of 23 and 33 approaches hot desert conditions (fig. 4). The whole area has a mild climate year-round with little variation in temperature from summer to winter. Heavy fogs and high humidity are the rule, but rainfall is nearly the lowest in the world. The desert areas east of the Andes (fig. 4) vary from warm to cool with the vegetation of the Monte resembling that of the Sonoran Desert. The Monte has a rating of 23 and the Patagonian Desert 12 and 13.

The Sonoran (24) Chihuahuan (13 and 23) and Mojave (14 and 24) deserts in North America (fig. 5) are usually considered warm deserts although the northern portion of the Mojave has cold desert affiliations and the Chihuahuan desert has a cooler aspect at its upper elevations. The 1979 UNESCO map shows only the Sonoran Desert in North America as qualifying as a hot desert.

DESERT LANDFORMS

The desert landscape includes landforms that may be common to other climates, but at least the particular aspect is characteristically a result of desert conditions. As I am sure these landforms will be discussed in more detail in this workshop, I should limit myself to mentioning some that may be said to lend character to the desert landscape and in listing these I am aware of differences in terminology and will not attempt to list all local terms nor make fine distinctions in the use of terms. These include the following:

Table 1.--Desert Landforms

mountains and inselbergs
bajadas
washes or wadis
plateaus and hammadas
regs, gobis, serrirs
featurless plains
playas - takyrs, chotts, sebkas, salinas
sand seas, dunes, ergs
exogenous rivers
caliche and calcretes

Mountains are common in and around deserts, varying greatly in geologic origin and height, but all having a bold, rugged aspect as compared to those of humid climates.

In nearly all cases the foot of the mountain makes sharp contact with an outwash alluvial slope called a bajada in the Americas. The bajada is typically deeply cut by a complex pattern of washes or wadis, which are dry most of the time but carry tremendous amounts of water and detritus during infrequent floods.

In a strict sense the term hammada is applied to plateaus with bare surface bedrock, but in a broad sense the term has been applied to shallow rocky soils which are widely distributed through desert areas.

Soils with small surface rocks termed gobi, serrir, gibber and reg are also common to all deserts. The surface cover of these is often referred to as desert pavement. Many of these have developed a carbonate layer called caliche in the American Desert and calcrete in Australia.

In undrained slight depressions, salt and water may accumulate and in time a poorly drained shallow basin called a playa in North America and takyr in Asia is formed.

Depressions where salts accumulate in large quantities because of a geologic history or a shallow water table are called chotts, sebkas or salinas depending on what country they occur in. Among the largest are the great salt desert in Iran and the salinas in Argentina.

While not restricted to deserts, sandy areas are common to most of the deserts of the world, making up from less than 1 percent in the North American Desert to dominant coverage in the Asiatic deserts and the Rub 'al Klhli in the Arabian Peninsula. The name Kara-Kum means black sands, Kyzyl-Kum red sands. The Taklamakan is largely sandy and even the Gobi, named for its gravely soils, has extensive sand areas. The Libyan sand area in the Sahara is as large as the whole of France and the Grand Erg Occidental in Algeria is second in size. The deserts of southern Africa, South America and Australia all have large areas of sand. In the global context, however, con-

sidering all deserts, world sandy areas are found only on a fourth to a third of the land surface.

Sands may be stabilized on flat lands or swept into dunes 200 to 400 meters in height and many kilometers in length. They may be longitudinal, sigmoid, or crescentic dunes including barchans, depending on the direction and intensity of the winds.

Many deserts include exogenous streams that originate in mountains and carry water to low lying desert areas. These are universally used for irrigation but in many cases the irrigated land has been destroyed by high water tables and salt accumulation. Better known rivers include the Nile, Colorado, Euphrates, Indus, and Yellow or Hwang Ho River, but there are many others.

Lime accumulations called caliche in North America and calcrete elsewhere are common through all deserts. These may form thick layers below the soil surface and are often exposed by erosion.

DESERT SOILS

The characteristics of desert soils will be covered in detail by other workshop participants so I shall just briefly note that they have well marked characteristic features related to climate and scanty vegetation. They are dominantly immature and exhibit characteristics related to parent materials. They have little humus and tend to be sandy or silty with a low clay content compared to soils of more humid climates.

Because moisture from precipitation does not percolate deeply, soluble salts tend to accumulate at a depth related to moisture penetration. Salts may accumulate in sufficient quantities to be toxic to vegetation, still further reducing plant cover beyond that resulting from scanty precipitation.

VEGETATION

Desert vegetation has both visible and invisible adaptations to life in regions of scant precipitation, high temperatures and excessive evaporation. The visible adaptations include structural characteristics to minimize moisture losses, root systems to make maximum use of evanescent soil moisture, water storage tissues, and modified life cycles to escape or endure dry periods. This includes survival through dry seasons as seed or bulb and combining stem and leaf photosynthetic tissue, and the dropping of leaves or even stem tips during dry periods. The invisible include physiological adaptations to obtain moisture by high cell sap concentration and reduction of moisture losses by photosynthetic processes involving minimum transpiration.

The vegetation of deserts has largely originated in the vicinity of the deserts, and there is little relationship of plants between major desert regions. There are however strong relationships in northern Africa and the warm deserts of Asia, and between North and South America. Succulents make up a prominent part of the flora in the Americas and Southern Africa, but the succulents of the two areas are not closely related. The Cactaceae is the dominant family in the Americas and Euphorbiaceae in southern Africa.

FAUNA

There is a surprising variety of animals in deserts. They include representatives of the larger mammals, birds, amphibians and a horde of insects. As noted with plants they have various anatomical and physiological adaptations to conserve moisture as indicated in Table 2.

Man has lived in deserts for many years, long before dry records show any activity, and with the aid of underground and surface water he probably will make greater use of deserts in the future. But that is what this workshop is all about; so I will leave the discussion to others.

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Table 2.--The Ecological Methods by Which Plants and Animals Meet Drought Conditions (After Shantz, 1956)

Plants	Animals
Drought-escaping	
Ephemerals which grow during moist seasons and live through dry seasons in the seed stage.	Animals that enter arid lands only when moisture is available - largely insects and other invertebrates.
Drought-evading	
Plants making economical use of limited soil moisture supply through wide spacing, reduced leaf and stem surface.	Burrowing animals, with night activity, that do not need to provide water for temperature control.
Drought-resistant	
Succulents that store water and are able to continue growth when soil moisture is not available. Not characteristic of extreme deserts.	Animals that resist drought through physiological processes by which they are able to concentrate their urine, lose little water in the feces, stop perspiration, endure dehydration and still remain active - the camel is a fine example.
Drought-enduring	
Drought-dormant plants that estivate when drought occurs and continue growth when moisture is available. This includes many prominent desert seed plants and also algae, lichens, mosses and ferns.	Animals that estivate and any invertebrates that recover after desiccation. Also vertebrates such as ground squirrels and gophers that estivate during hot dry periods.

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RESUMEN

Luego de considerar las causas de la aridez, se describen los climas de los desiertos, se muestra en los mapas la localización de los desiertos calientes, y se discuten sus características. Se discuten brevemente las formaciones de tierra en el desierto, los suelos, la vegetación y la fauna.

Los Desiertos de México[1]

Ing. Avelino B. Villa Salas[2]

RESUMEN.- En este trabajo se indica que los desiertos de México ocupan poco menos de la superficie total del país, por lo que es necesario obtener un mejor conocimiento de sus características para poderlos manejar de una manera racional y permanente; también se describen las características de las zonas áridas y semiáridas de México, en cuanto a sus suelos, clima y vegetación. Sobre la vegetación, en forma especial se citan un gran número de especies que se han venido utilizando con diferentes propósitos, que es necesario cuantificar para conocer su distribución.

Aunque todavía no es posible contar con cifras exactas con respecto a la extensión, - delimitación y la definición precisa de las zonas áridas y semiáridas que forman los desiertos de México, debido a las discrepancias entre los especialistas, nadie puede - negar la importancia que ya tienen para el desarrollo regional.

En México se consideran zonas áridas a aquellas áreas cuya precipitación es menor de -- 350 mm al año, con una distribución de lluvias muy irregular durante el ciclo vegetativo, con una temperatura media anual que oscila entre los 15 y 25ºC, con la presencia de no menos de 7 meses de sequía y que tienen - una cubierta vegetal menor del 70%, denominando principalmente especies xerofíticas.

Las zonas semiáridas, se definen como aquellas áreas cuya precipitación pluvial varia 350 a 600 mm al año, su cubierta vegetal es superior al 70% y la vegetación dominante es formada principalmente por diferentes tipos de matorrales y pastizales naturales.

Estos dos tipos de áreas, las áridas y semiáridas, de acuerdo al Inventario Nacional Forestal y bajo las definiciones anteriormente mencionadas, cubren una superficie de 90 millones de hectáreas, lo que equivale a poco menos de lamitad de la superficie total del país.

[1]Trabajo presentado en el Evento Internacional, "Inventarios de Recursos de Zonas Aridas", La Paz B.C.S., México, Nov. 30-Dic. 6, 1980.

[2]Subsecretario Forestal y de la Fauna, México.

Estas áreas se localizan principalmente en los llamados Desierto Chihuahuense, Desierto Sonorense y Desierto de Baja California.

Los desiertos Sonorense y Chihuahuense, se han originado principalmente por la ubicación de - macizos montañosos, los cuales forman una barrera cerrando el paso de los vientos húmedos, provocando así la ausencia de lluvias a las - tierras del interior: Este fenómeno se produce cuando los vientos húmedos chocan con el macizo montañoso, enfriándose a medida que se elevan y descargan toda su humedad en las vertientes del Barlovento, cuando estas masas de aire descienden sobre las vertientes del Sotavento se han transformado en vientos secos que absorven rápidamente la poca humedad en esad áreas, formando evidentes condiciones de aridez.

El desierto de Baja California es un desierto costero, denominado desierto de Neblinas, y se forma por lacirculación de los vientos provenientes del poniente, los cuales se enfriaron por las corrientes oceánicas que bañan sus litorales.

Por lo que respecta a suelos de zonas áridas y semiáridas de México, existe una gran variabilidad de los mismos, presentando una gama de - colores como el dorado, ocre, rosa, carmesí, - blanco, o bien matices más obscuros según la - región de donde procedan; las texturas pueden ser pedregosas, gravosas, francas, arcillosas, de roca desnuda o revestida de gruesas costras de sal; la estructura es por lo general granular, con drenaje interno medio, de consistencia friables, con un pH que varía de 6.8 a -- 7.6; los niveles altitudinales que se presentan en las zonas áridas oscilan de 250 a 1800 mts.

sobre el nivel del mar; geologicamente estas áreas estan representadas por los períodos Cretásico Inferior, Cretásico Medio, Cretásico Superior, y Cenozoico Clástico; El Cretásico Inferior esta formado por calizas; en el cretásico Medio se encuentran aluviones, conglomerados de calizas, calizas compactas con concentraciones ferruginosos y módulos de pedernal; el Cretásico Superior consiste en gruesos bancos de calizas casi horizontales; el período Cenozoico Clástico se sitúa tanto en la planicie como en las laderas y consta de arcilla, arena y aluviones en las partes planas, en las laderas se forman conos de deyección con aluviones conglomerados de arcillas.

Pretender definir los diversos problemas que agobian a los desiertos de México, significaría todo un tratado, por lo que solo se mencionarán algunos de ellos, como son: La existencia de poblados pequeños y diseminados, lo que propicia que los servicios públicos elementales sean deficientes, así mismo se dificulta el crédito y la asistencia técnica; ésto, aunado a la falta de lluvias bien distribuidas, al sobrepastoreo, al desconocimiento del uso adecuado de las especies y a la falta de infraestructura tanto económica como social, tiene como principales efectos los bajos rendimientos en la producción agrícola, ganadera y forestal, además de la destrucción de la cubierta vegetal, lo que propicia que los suelos queden expuestos a la erosión y sean degradados tal vez con efectos irreversibles propiciando evidentes procesos de desertificación.

A pesar de la problemática anteriormente expuesta, y a las características extremosas del clima y del suelo de estas regiones, se alcanzan a desarrollar una gran cantidad de especies nativas que son de suma importancia para los pobladores de las zonas áridas de México; por lo que respecta al desierto Chihuahuense destacan las siguientes especies: El mimbre Chilopsis linearis, que es utilizado en la fabricación de muebles, cabos de hachas y azadones; la barreta Helietta parvifolia, que es muy apreciada como postes para la instalación de cercos; el mezquite Prosopis sp., cuya madera es utilizada en la fabricación de duelas, obtención de carbón, "Parket", muebles,curvos para cascos de pequeños barcos camaroneros, briquetas, postes para cercas, hormas para zapatos, etc., La Albarda Fouquieria splendens, que se utiliza en la elaboración de artesanías; y diferentes especies del género Yucca, utilizadas para la obtención de fibras, combustibles, sarsasapogenina, alimentos para ganado, material de construcción, como medicinal, etc. Además de las especies anteriormente mencionadas, existe una serie de plantas consideradas como industriales que de una manera u otra han sido la base para la subsistencia de los poblados de las zonas áridas y semiáridas, entre estos se destacan las siguientes: La Lechuguilla Agave lechuguilla, cuya fibra es aprovechada en la fabricación de cepillos, sacos y cordelería, actualmente es utilizada por cerca de 2,000 familias campesinas en México; La Candelilla Euphorbia antisyphilitica, especie que es una fuente natural de cera, misma que es utilizada como diluyente de otras ceras, para elaborar velas, goma de mascar, recubrimiento de frutas para exportación, en odontología, en explosivos, en la preparación de pinturas, en materiales contra insectos, en la fabricación de compuestos de celuloides, etc., actualmente viven de ella 3,000 familias campesinas; El Guayule Parthenium argentatum, que es una fuente natural de hule, al cual actualmente se le ha podido eliminar los altos contenidos de resinas mejorando satisfactoriamente la calidad de este producto; La Gobernadora Larrea tridentata, es una especie que posee considerables concentraciones de ácido norhidroguayaretico, el cual es utilizado como antioxidante en la industri alimenticia. También contienen resinas que se usan como base para pinturas y barnices, de esta especie tambien se extrae fungicidas del tipo fenólico.

En el desierto Chihuahuense se cuenta ademas con una gran cantidad de gramíneas, formando pastizales que son utilizados para la cria de ganado; ademas, existe una gran cantidad de arbustos forrajeros, como son la Costilla de Vaca Atriplex canescens, el Guayacán Acacia berlandieri, el Ramoncillo, Dalea tuberculata, el Saladillo Atriplex Acanthocarpa y muchos arbustos más que contribuyen en la alimentación de ganado,. En estas áreas, es común también encontrar una gran cantidad de especies forestales, que son utilizadas por sus habitantes como medicamentos, entre estas podemos mencionar a la Albarda Fouquiera splendens, al chaparro prieto Acacia rigidula, el cenizo Leucophyllum texanum, a la Candelilla Euphorbia antisyphylitica, al Toloache Datura stramonium, a la anacahuita Cordia boissieri, a la Calderona Krameria ramosissima, al Hojasen Flourensia cernua, al orégano Lippia sp., etc. además es importante mencionar que en estas zonas se encuentran diferentes especies de cactáceas, que son muy apreciadas para ser utilizadas como plantas ornamentales.

Independientemente de la utilización de estas especies, es necesario destacar la importancia del Nopal, ya que tanto los Cladodios tiernos como su fruto son aprovechados para consumo humano.

Por lo que respecta al desierto Sonorense y al de Baja California, existen una gran cantidad de especies que son utilizadas en forma tradicional, entre las que destacan la Jojoba Simmondsia chinensis por sus grandes contenidos de cera líquida, utilizada en la elaboración

de ceras, aceites, cosméticos, lubricantes,- etc., la Damiana Turnera difusa, usada en la elaboración de licores, infusiones y como medicamentos; el Palo Mauto Lysiloma divaricata, y Palo Blanco Lysiloma candida, ambos como curtientes; Orégano Lippia palmeri, usado como condimento de alimentos; el Palo Adán - Fouquieria diguetti utilizado en la elaboración de jabones, y la pitaya dulce Lemaireocereus thurberi, útil en la elaboración de - conservas. Por lo que respecta a especies forestales se pueden mencionar al Palo Amari - llo Esembechia flava, al Palo Escopeta Albizzia occidentalis y al Palo Zorrillo Cassia-Emarginata; estas tres especies son utilizadas como postería: el Guervio Populus bran - degii, es usado en elaboración de muebles; - el Palo de Arco Tecoma Stans, en la construcción de muebles y casas, el Palo Adán Olneya tesota, en la fabricación de muebles, el Palo Mauto Lysiloma divaricata, para postería- y el encino Quercus spp., en la fabricación- de muebles.

Entre las especies susceptibles de ser usa - das en la elaboración de artículos artesanales, se pueden mencionar al cardón Pachyce - reus pringlei, a la Cholla Opuntia cholla ,- a la Pitaya Dulce Leumaireocereous thurberi, al Chilicote Erythrina flabelliformis y al - Cajolosuchil Plumeria acutifolia; además se- encuentran distribuidas gran cantidad de especies de pastizales y arbustos forrajeros , que son utilizados en la alimentación del - ganado.

Las áreas desérticas mencionadas, son ricas- en fauna silvestre, entre las especies más - relevantes en el desierto Chihuahuense, se - pueden citar el conejo de Audubon Sylvilagus audubonii, las liebres de cola negra Lepus - californicus, el perrito de la pradera --- Cynomys mexicanus, el Coyote Canis Latrans , el Lobo Canis lupus, la Zorra Norteña Vulpes velox, el oso negro Ursus americanus, el oso plateado Ursus arctos, el Tlalcoyote Taxidea taxus, el puma Panthera concolor el Jabalí Tayassu tajacu el venado bura Odocoileus -- hemionus, el venado cola Blanca Odocoileus - virginianus, el Berrendo Antilocarpa americana, el Bisonte Bison bison, el Aura Cathartes aura, el Aguila Real Aquila Chysaetos, el Correcaminos Geococcyx californianus, la Codorniz Escamosa Callipepla squamata, la Hilota- Macroura zenaida, la Tortuga del Desierto -- Gopherus slavomarginatus, la Víbora de Cascabel Crotalus seutulatus y el Coralillo Micruroides sp. por lo que respecta al desierto - sonorense se puede citar a la Liebretorda Lepus alleni, a la ardilla rojiza Seiurus arizonensis, al Coyote Canis latrans, a la zorra gris Cinereoargentus, al tejon Nabua narica,

al zorrillo listado, Mephitis macroura, al - jabalí Tayassu tajacu, al venado bura Odocoileus Hemionus, al venado cola blanca Odocoileus virginianus, al berrendo Antilocarpa - americana al borrego cimarrón Ovis canadensis, a la codorníz de gambell Lophortyx - gambellii, al zopilote Coragyps atratus, al escorpión o monstruo de gila Heloderma sp., a la víbora de cascabel Crotalus cerestes. Por último, en el desierto de la Baja California, tenemos al conejo matorralero Sylvilagus bachman, a la ardilla de douglas Tamiasclurus douglasii, al zorrillo listado Mephitis, al venado bura Odocoileus Hemionus, al borrego cimarron Ovis canadensis, al cońdor de california Gymnogyps californianus, al aura y a la codorníz de Lophortyx californicus.

Como se ha podido observar en el transcurso de esta exposición, es incuestionable que - las zonas desérticas del país constituyen - un gran potencial para su desarrollo económico, ya que no sólo ocupan una superficie- considerable del territorio, sino además poseen una gran variedad de recursos de fauna y flora silvestre.

Sin embargo, es conveniente antes de pensar que en el desierto tenemos una solución mágica a muchos problemas, en la necesidad de cuantificar su potencial, ya que su equilibrio ecológico es muy frágil y fácilmente podría alterarse en forma tal, que costaría mucho tiempo recuperarlo.

También es conveniente llamar la atención al hecho que surgen, como en el caso de la Jojoba, ideas exageradas sobre características que promueven su cultivo, ignorando las importantes superficies donde crece en forma expontánea y sólo se requiere manejar y mejorar las poblaciones silvestres.

El desierto de México, puede ser un importante factor en el desarrollo socioeconómico del país, solo es necesario saber cuantificar el potencial de las diversas especies - vegetales y animales para lograr su manejo adecuado, que nos permita obtener alimentos y materias primas en forma permanente sin menoscabo de su potencial.

ABSTRACT

This paper points out that the deserts in Mexico occupy most of the total surface of that country. For this reason we must obtain a better knowledge of their characteristics in order to be able to manage the deserts in a proper and permanent manner. This article also describes the characteristics of the arid and semi-arid zones of Mexico, including their soil, climate, and vegetation. Specific mention is made about a great number of vegetative species which have been utilized for various purposes, and which must be quantified in order to determine their distribution.

Characteristics, Resources, and Uses of Hot Deserts of the United States[1]

S. Clark Martin[2] and David R. Patton[3]

Abstract.--The hot deserts of the United States provide desirable living conditions, recreational amenities, and employment opportunities for rapidly expanding populations but resources cannot meet all wants and needs. Inventories are necessary for rational allocation of resources among competing uses.

INTRODUCTION

Resource inventories for arid lands is the subject of this conference. Our assignment under this topic is to describe the hot deserts of the United States, their resources and uses. Much research has already been done by the University of Arizona, Arizona State University, California Institute of Technology, New Mexico State University, the University of Texas at El Paso and Texas Tech University on the hot deserts of the U.S. The Carnegie Desert Laboratory at Tucson conducted desert research between 1900 and 1935. More recently, under the International Biological Program, almost all of the educational institutions in the region have been involved in desert research. Finally, the U.S.D.I. Bureau of Land Management has made a detailed analysis of the deserts of California, Arizona and Nevada and is summarizing their findings in a series of environmental statements. As we approach the work of this conference, it is reassuring to know that we are building on a solid information base.

This paper describes the resources and uses of the Chihuahuan Desert of New Mexico and west Texas, the Sonoran of western Arizona and southeastern California, and the Mohave of California and southern Nevada (fig. 1). These deserts cover about 73 million acres (30 million ha) of which 67 percent is in Arizona and California, 15 percent in southern New Mexico, 10 percent in Nevada and 8 percent in west Texas. Added together these deserts would occupy an area equal to the state of Arizona.

The desert land surface is mostly flat to moderately sloping and is dissected by numerous gullies or arroyos. Ranges of mountains and hills break the monotony of the general plain. Elevations range from below sea level in the lower valleys of California to about 3,500 feet (1,070 m) above sea level in New Mexico. At its upper edge the deserts merge with grassland or grass-shrub associations on the foothills or bajadas of included mountain ranges.

Runoff from the Chihuahuan and Sonoran Deserts flow toward the Rio Grande and the Colorado rivers respectively via major tributaries such as the Gila and the Pecos. Much of the runoff in California and Nevada flows inward to usually dry playas, or to the Salton Sea 270 feet (82 m) below sea level; the remainder drains toward the Colorado. Most desert runoff is local, however, as the water is soaked up by dry streambeds long before it reaches a major stream.

LAND OWNERSHIP

In California, Arizona, and New Mexico a majority of the desert is publicly owned. The U.S. Department of Interior is the largest landholder. It administers these lands through the Bureau of Land Management, Water and Power Resources Service, and the Park Service. The Bureau of Indian Affairs is custodian for large acreages of lands held in trust for Indian tribes. Several large blocks of desert are administered by the U.S. Department of Defense and individual states have a number of parks as well as substantial acreages in scattered parcels. Private land holdings are small because the desert was not attractive for homesteading and the acreage that went to patent as mining claims was not large.

The largest transfers to private ownership occurred from homesteading of irrigable agricultural lands and land close to developing population centers, and grants of alternate sections of land to railroads. By contrast, the desert of Texas is

[1]Paper presented at "Arid land resource inventories: developing cost-efficient methods", an international workshop. (La Paz, Mexico, November 30-December 6, 1980).

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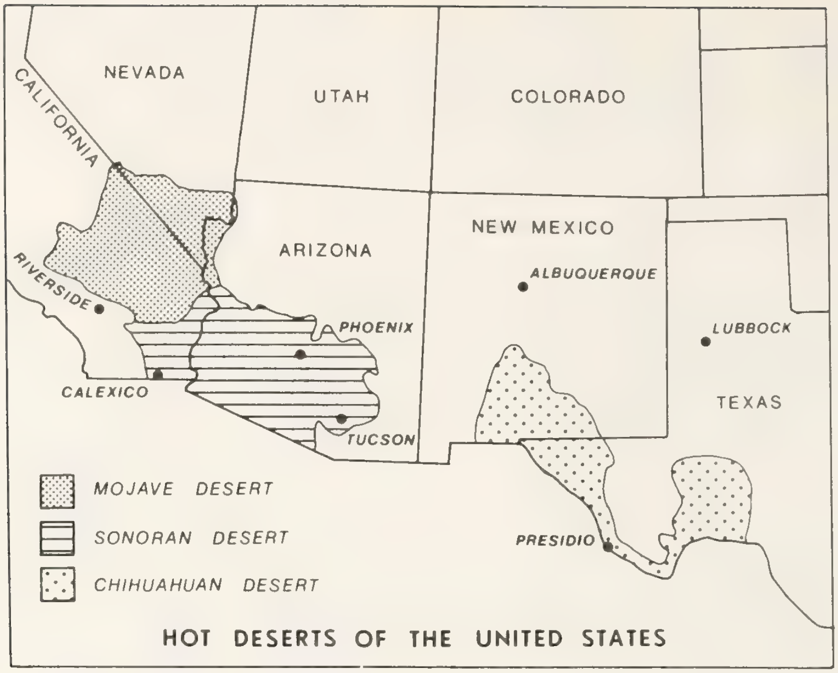

Figure 1.--Approximate areas occupies by hot deserts of the United States.

privately owned; two exceptions being the desert portion of Big Bend National Park and the military reservation at El Paso. The ownership of desert land is not static, however. Exchanges to consolidate ownerships are frequently arranged to simplify administration, or make more efficient use of resources.

CLIMATE

The climate of the desert is both a characteristic and a resource. Hot summers, mild winters and low precipitation are characteristic. July mean temperatures range from 81 to 90 degrees F (27 to 32 C) with maximums of 106 to 117 F (41 to 47 C). January means are 45 to 55 degrees F (7 to 13 C) with minimums as low as -7 to -17 F (-22 to -27 c). The frost-free period ranges from 231 to 323 days, with the first killing frost as late as December 16 and the last spring frost as early as February 1. Higher mountain ranges within the region are islands of cooler temperature, higher precipitation and more mesic vegetation.

Annual precipitation ranges from about 1.5 inches (40 mm) in the driest parts of California to 10 inches (250 mm) or more at upper elevations of the Sonoran and Chihuahuan deserts in Arizona and New Mexico. Not only is precipitation low, it is highly variable from year to year and seasonal distribution changes from west to east. Warm-season (April to September) rainfall accounts for only one third of the yearly total at Calexico, California, for example, but makes up two-thirds of the annual total at Presidio, Texas (fig. 2). This means that summer rainfall in much of the California and Nevada desert averages only about one inch (25 mm) compared to 5 to 6 inches (125 to 150 mm) in New Mexico and Texas. The Sonoran desert in Arizona lies between, with warm-season precipitation increasing from west to east.

Desert summers are hot; truly not fit for man or beast. Man, like other animals of the desert, persists here largely by avoiding the heat. We are reminded of this periodically by deaths of persons who have ventured ill-prepared into the desert and become lost or stranded. Thirteen persons died in Arizona's desert in July 1980. Man modifies the environment by building shade devices or planting trees. Before air conditioning we opened our houses to the cool night air and closed them up during the day. Evaporative coolers, the first great climate modifiers, enabled us to keep our houses comfortable during most of the summer because the humidity is usually very low. Backyard swimming pools and summer cabins in nearby mountains also provide relief from summer heat. Now we can be comfortable even in hot sticky weather with air conditioners in our houses, offices, factories and even in our buses and cars. We, like the lizards, have learned to hurry from one cool spot to the next.

The hot cloud-free days of the desert offer compensating benefits. One is rarely house-bound in the desert because of the weather. One can work efficiently in the desert heat if he drinks

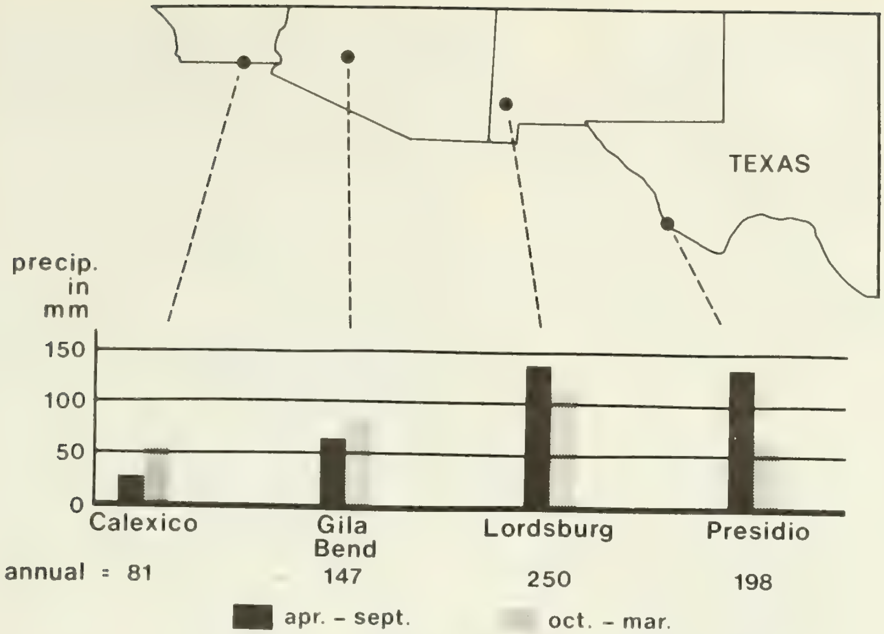

Figure 2.--Annual and seasonal precipitation in the hot deserts of the United States.

enough water (1-2 gallons; 4-8 l per 8-10 hour work day), wears a hat and uses enough salt to replace loss by perspiration. Low humidity keeps the body acceptably cool by evaporative cooling.

The real attraction of the desert, for living, is the mild sunny winters. Rarely is it too cold to enjoy being outdoors in light clothing. Hiking, golf, tennis, shuffleboard and similar activities can be enjoyed out-of-doors almost any day in the year. There are other advantages. The cost of heating a desert home is small compared with a home in the northeastern part of the United States, and there are no icy roads. Automobile bodies last longer because they are rarely wet and because street salt is not eating away at the car's underside. Finally, many who suffer from arthritis or respiratory ailments are more comfortable in the dry warm atmosphere of the desert.

SOILS

The typical desert soils consist of lithosols on mountains, medium to coarse-textured red desert, desert, or sierozem soils on alluvial fans and terraces, and alluvial, solonchak, or solonetz soils in the bottoms. Red desert soils are typical. They occur on topograpy that is gently undulating to flat with long slopes on alluvial fans and terraces. Red desert soils have sandy loam to silt loam A horizons that usually are less than 6 inches thick. The underlying B horizon is thicker, redder, and a little finer-textured than the surface layer. Calcium carbonate layers are found in the lower B horizons, and they are sometimes cemented. Internal drainage is good and they are non-saline in the upper horizons. A gravelly surface (desert pavement) is characteristic and contributes to the stability of the surface and its resistance to wind and water erosion (Springer 1958, Denny 1965). Localized dunes are common. Red desert soils are common in the hot deserts of California, Arizona and New Mexico, but are less extensive in the Chihuahuan region. The Pecos valley of New Mexico and Texas is distinguished by a large block of Calcisols. Recent alluvial soils are important for irrigated agriculture. Large areas of alluvial soils occur in the Gila and Salt river valleys of Arizona, the Imperial Valley of California and along the Rio Grande, but such soils more commonly occur as narrow flood plains.

LAND AND WATER

As you cross the desert, from El Paso to San Diego, or Los Angeles, you get the impression that land is abundant--almost limitless. Much of the land is flat and physically suitable for agriculture and almost all appears suitable for residential or commercial building, but the desert is deceiving. Some of those apparently desirable building sites are subject to infrequent torrential flooding, and most of the apparently suitable land does not have enough high quality water under it, or available to it, to support either extensive irrigated agriculture or large urban populations.

Underground water that has accumulated in the alluvium of desert valleys beginning as the alluvium itself was laid down is now being pumped for agricultural, industrial, municipal and domestic use at many desert locations. Almost without exception, the quantity of water pumped exceeds the rate of recharge. As the water tables fall, and pumping costs increase, poor-paying uses or users drop out or are replaced by those that can afford the higher water costs. The usual sequence when underground water has been found in a desert basin is that the acreage irrigated first expands rapidly, then follows a period in which the falling water table and increased pumping costs reduce the irrigated acreage to an area that can be supported more permanently.

Most of the irrigation projects and communities that are founded entirely on underground water are relatively small. The larger tracts of irrigated land in the Salt River Valley in Arizona and the Imperial Valley in California and the metropolitan area around Phoenix are supported by water from streams that originate outside the desert. Tucson, Arizona, is the largest city that depends entirely on underground water, but it has been forced to bring water in from wells far beyond the city limits.

The Central Arizona Project is being built to bring Colorado River water to the Phoenix area and to Tucson to help offset an increasing groundwater deficit. The reservoir systems on the Salt and Verde rivers simply do not furnish enough water to prevent further depletion of groundwater. It is obvious, therefore, that the development and use of desert land for farms and cities is limited by the water supply. We could make the entire desert bloom if only we had enough water. Since water is limited, there will have to be changes in its allocation and use.

VEGETATION

Perennial vegetation throughout the hot United States deserts is mainly shrubs and succulents. Plants are larger and more numerous along water courses and in depressions that receive runoff. Between the water courses, the shrubs become smaller and more widely spaced with increasing aridity. The hot deserts of the United States are not so arid that plants do not occur at all. Rather, our deserts fit somewhere between "semiarid" with sparse vegetation of great variability and "desert" where perennial plants occur only in the most favorable sites (McGinnies 1968).

The hot desert region of the United States conforms generally to the area mapped by Shantz (1924) as creosotebush (*Larrea tridentata*) (Southern Desert Shrub). Brown (1964) subdivides this region into: Mohave Desertscrub, Sonoran Desertscrub-Arizona Upland Division, Sonoran Desertscrub-Lower Colorado Division, and Chihuahuan Desertscrub as described by Lowe (1964). The northern edge of the hot desert is defined generally by the northern limit of creosotebush and associated species that periodically are pushed back by cold air from the north or are held in check at the upper rainfall limits of the desert by competition from plants that are better able to utilize moisture of more mesic environments.

Although creosotebush occurs on selected sites throughout the hot desert region of the United States, its associates or co-dominants differ from place to place. In the Chihuahuan Desert, for example, creosotebush commonly occurs with tarbush (*Florensia cernua*), or whitehorn (*Acacia constricta* or *A. neovernicosa*); in the Sonoran the co-dominants might be triangleleaf bursage (*Ambrosia deltiodea*) or blue paloverde (*Cercidium floridum*); in the Mohave creosote bush occurs with Joshua tree (*Yucca brevifolia*), other yuccas, or white bursage (*Ambrosia dumosa*). We do not imply that creosotebush is found everywhere within the desert. For example, Brown and Pase (1979) list 10 or more plant associations in which creosotebush is not dominant or co-dominant for each of these deserts. Low growing forms of mesquite (Prosopis) are also found in all three deserts. Rather typical associations other than those including Prosopis or Larrea are: Joshua tree-blackbrush (*Coleogyne ramosissima*) and blackbrush-yucca in the Mohave; paloverde-ironwood-smoketree (*Cercidium floridum*-*Olneya tesota*-*Dalea spinosa*) and triangleleaf bursage-sahuaro (*Carnegiea gigantea*) in the Sonoran, and the sandpaperbush-skunkbush (*Mortonia scabrella*-*Rhus trilobata*) and lecheguilla-yucca (*Agave lecheguilla*) associations in the Chihuahuan.

Warm season perennial grasses are restricted by low summer rainfall to the most favorable sites in the Mohave and Sonoran deserts. Big galleta (*Hilaria rigida*), a coarse stemmy bunchgrass does occur on selected upland sites. Other perennial grasses include three-awns (*Aristida spp.*) and gramas (*Bouteloua* spp.). Most of the grasses in these drier areas are located along water courses, in low places, or in the shade of shrubs where they are not exposed to the full rigors of the desert climate. From central Arizona east, gramas (*Bouteloua* spp.) three-awns (*Aristida* spp.) and associated perennial grasses are common along water courses, but are generally absent from sites that are dependent entirely on direct rainfall. Vegetation along drainages that originate in higher rainfall zones outside the desert is always more lush than local precipitation will support. Species typical of desert grassland, or even more mesic habitats, are supported within the desert boundary by imported water. These more lush areas of vegetation provide habitat for wildlife that otherwise would not be able to survive.

Yields of annual grasses and forbs vary greatly from year to year in response to differences in rainfall. Even the driest California deserts produce a substantial cover of annuals in the spring following a wet winter. Common species are gold poppy (*Escholtzia californica*),

alfilaria (Erodium cicutarium) and several genera of crucifers (Cruciferae), borages (Borafinaceae), and legumes (Leguminosae) as well as annual grasses, mainly bromes (Bromus), fescues (Festuca) and barleys (Hordeum). These plants germinate in the late fall, spend the winter in a rosette stage, then mature rapidly as temperatures rise in the spring. These annual species of the California and Nevada deserts exhibit much the same pattern of behavior in western and central Arizona, but winter annuals rarely make much of a show in the Chihuahuan zones of New Mexico and Texas. Warm season annuals, on the other hand, form a substantial part of the ground cover following summers of high rainfall from central Arizona eastward. Annual gramas and aristidas fill the spaces between perennials when there is more moisture than the perennials can use. Production of warm-season annuals is negligible in the deserts of California, Nevada and western Arizona because of the extreme summer drought. Throughout the desert region, annuals are opportunistic. They produce abundantly in exceptional years and next to nothing in average to poor seasons.

GRAZING

The hot deserts of the United States provide forage for various classes of domestic livestock. In Arizona and New Mexico the desert ranges are used almost exclusively by cattle. In Texas goats and sheep are run with the cattle, whereas in California cattle and sheep are used but separately. In western Arizona, California and Nevada feral burros run wild on much of the desert range.

From southern Arizona eastward, ranges are stocked with resident herds of breeding animals at the average capacity of the range, but with animal numbers adjusted to year-to-year differences in forage yield. Forage in these areas is produced mainly during the summer rainy season and whatever forage is on the ground at the end of September must carry the animals through until about mid-July of the following year.

From central Arizona westward across California, winter annuals constitute the main forage crop. Since annuals do not yield useable forage every year, many of these ranges are stocked only when there is a good crop of annuals. Other ranchers carry a small resident herd through the year and buy steers to use the extra forage when high winter-spring precipitation grows a worthwhile spring forage crop.

The total number of animal units grazed on the desert ranges is relatively small for so large an area. It is common to allot 200 to 300 acres per animal unit (a cow, plus her calf from birth to weaning) for resident desert herds. This suggests that about 73 million acres (30 million ha) of desert will carry 250,000 to 350,000 animal units.

RECREATION

The attribute most abundant in the desert is space. There is ample room to enjoy solitary recreational activities. Hiking, bird watching, nature photography, picnicking, camping, rock hounding, horseback riding and off-road vehicle sports are all popular. Such activities rarely have to be postponed because of weather.

Cross-country races and desert exploration by trail bike, jeep or other 4-wheel drive vehicles are favorite recreational activities. Such activities are especially popular within easy driving distance of southern California's population centers. However, vehicle traffic breaks through the erosion pavements that formerly protected the soil surface, leaving the area subject to severe sheet and gully erosion when it does rain. The scanty desert vegetation is largely destroyed and the habitat of desert wildlife is altered. Even the desert sand dunes, which have some of the self-renewing properties of a beach, are the natural habitat for a few species that may be affected adversely by heavy and frequent vehicle traffic. Many vehicle recreationists feel, however, that the desert cannot be hurt and that it doesn't really matter anyway. This viewpoint runs contrary to that of persons concerned about loss of suitable habitat for desert wildlife. People who go to the desert to enjoy its quiet and solitude are likewise rankled by the noise and dust created by off-road vehicles as well as by those who bring sounds of the city with them via stereo tapedeck and amplifier.

WILDLIFE

The hot deserts of the United States provide habitat for over 350 species of amphibians, birds, fish, mammals, and reptiles. This includes important groups such as game: javelina (Dicotyles tajacu), desert bighorn (Ovis canadensis), desert mule deer (Odocoileus hemionus), Gambel's quail (Lophortyx gambelii), and mourning dove (Zenaidura macroura); furbearers: bobcat (Felis rufus) and coyote (Canis latrans); and threatened and endangered species: peregrine falcon (Falco peregrinus), Colorado squawfish (Ptychocheilus lucis), and Gila topminnow (Poeciliopsis occidentalis). Of the game species, deer, dove, and quail probably account for most of the hunting experiences for desert country residents. Fishing for largemouth bass (Micropterus salmoides) and channel catfish (Ictalurus punctatus) is a major activity along the Colorado River and in dam and reservoir systems.

One of the most important plant associations for wildlife, especially birds, within the hot desert geographic area is riparian vegetation. Riparian zones, usually characterized by mesic vegetation (cottonwood, willow, alder, etc.) and more-or-less permanent surface water, provide

a welcome contrast to adjacent dry subhumid environments. This zone is an area of major conflict in use between wildlife, livestock, recreationists and wood cutters.

INDUSTRY

Winter tourism is big business in the Southwest. The desert is a winter haven, both for those who wish to escape from winter in the Northeast for a couple of weeks and for those who are retired or can otherwise afford to spend most of the winter here. Many retirees, after a winter or two in the Southwest, learn to adapt to the summer as well. Sun City, near Phoenix, and Green Valley, south of Tucson, are examples of retirement communities that are thriving because of the desert climate.

Industry is being attracted to the desert because people like to live here. Some learned to like the desert during World War II as they trained for aerial or desert combat. The desert is ideal for high technology industry that does not require vast quantities of water. It is ideal for engineers and designers in electronics, computers, and research scientists in many fields. The desert, because of its relatively clear atmosphere and cloudless sky, has long been a center for astronomical research. It is a natural place to capitalize on solar energy.

Prospectors and their burros were among the first desert pioneers. They were looking primarily for gold and silver. Death Valley Scotty and "The Dutchman", whose lost mine in the Superstition mountains near Phoenix is still sought, were looking for gold. The mining industry in the desert, however, has been built on less precious commodities. Copper mining is a major industry in Arizona; a borax business thrived in California for a time, and exploration for oil is underway throughout the region. In Arizona mining employs about the same number of people now as it did in 1971 (Valley National Bank of Arizona 1979). Other sources of employment, however, have increased greatly during the same period. Gains in employment have been much greater in manufacturing, construction, wholesale and retail trade, transportation and utilities: businesses whose growth is related more strongly to population changes than to the availability of a specific mineral such as copper.

AIR QUALITY

Air quality is being monitored by local and state agencies mainly in urban areas of the desert but more information on air pollution levels, emission sources, and dispersion patterns is needed. Visibility is the most obvious measure of air quality in the desert. When present, pollutants from major urban centers form local or widespread haze that may reduce visual range from 100 km or more to less than 25 km. A related problem in the desert is city lights that illuminate the night sky and interfere with astronomical observations. Most of the pollutants in the California desert are carried in from the Los Angeles basin by prevailing winds. Pollutants in such cities as Tucson and Phoenix are highest in winter when still air and resulting inversion layers confine gases and particulates to a small volume of air. Local pollution sources consist mainly of particulate matter from unpaved roads, off-road vehicles, mining operations, and agricultural tillage. At times windblown dust from bare desert soils reduces highway visibility enough to constitute an extreme traffic hazard.

CHALLENGES

A burgeoning population is placing increasing demands on the desert for a spectrum of uses. Several million people live in or near the desert and an increase of 65 percent is expected by the year 2000. Society's ability to use and abuse the desert is increasing. Recreational use of the desert is increasing not only because of increased populations, but also because of greater affluence, improved technology, and increases in mobility and available leisure time. It appears that decisions to allocate desert resources among competing interests can only become more difficult.

The desert will and can be used, but we can't afford to use it destructively. Even so, we may not be able to save every species of desert life from extinction. We may not be able to preserve every ghost town, prehistoric campsite or trashpile. Standards of ecological or environmental purity may have to be modified to meet current human needs. Nature's crops and methods certainly won't feed, house, and clothe many people in the desert. As we look ahead then, we can expect that parts of the desert will be changed drastically for townsites, farms, mines, nuclear power, plants, pipelines, powerlines and highways. Other tracts will be set aside for wilderness, parks, archeological reserves, wildlife refuges or recreation areas. Additional lands will be left for undesignated multiple uses, including livestock grazing, hunting and other dispersed recreation. Arid land inventories can and should identify and locate areas that are most suitable for each use.

A common problem in vegetation inventory is that vegetation changes not only with the seasons but from year to year in response to changes in the amount and distribution of precipitation. Results of surveys conducted in favorable years will be quite different both quantitatively and floristically from those of surveys done during drought. The data collected in a survey, therefore, must be weighed according to the recent climatic record; especially if an extreme climatic event such as a 100-year flood or freeze, protracted drought, or unusually high and sustained

rainfall have occurred. A single extreme climatic event can affect the course of vegetation changes for many years.

The hot deserts of the United States are moisture deficient. We cannot change that. However, as you inventory these arid lands we hope you give particular attention to the desert edge. We need to monitor these transition zones to determine whether the desert is expanding because current management is changing habitats from semi-arid to arid. If so, we need to stop the destructive practices and push the desert back.

If the human element were omitted it would be relatively easy to prescribe cures for land abuse. It is difficult, if not impossible, however, to restore desert vegetation and meet all the needs and wants of those who use it. For persons at the bare subsistence level it may be impossible to postpone immediate benefits for long term gains. Likewise, miners, commercial interests and recreationists of whatever kind, who abuse the desert incidentally are quite ready to defend their "rights" to continue. It will be much easier to inventory the physical resources and attributes of the desert than it will be to allocate the use of its resources among competing users.

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CARACTERÍSTICAS, RISÓRSAS Y USOS DE

LOS DESIERTOS CALIENTE DE LOS ESTADOS UNIDOS

S. Clark Martin y David R. Patton

Tratamos aqui los desiertos Chihuahuan, Sonoran, y Mojave de Tejas, Nuevo Mexico, Arizona, y California. El terreno es de pendiente suave y disecado por varias desagües. Las montañas interrumpen el monótono de los lanos. La baja precipitación (50-100 mm anual) casi siempre occurré como lluvia, y la intensidad y espaciamiento de las tormentas es muy variable. La escorrentia de los desiertos Chihuahuan y Sonoran corre para los ríos Rio Grande y Colorado respectivamente, pero se consumé en los arroyos antes de llegar al río. La escorrentia en el Mojave corré hacia dentro para las playas, algunas abajo el nivel de mar.

La vegetación perennal consisté de arbustos cortos anchamente espaciados. Los arbustos son mas grande y mas numeroso a lo largo la corriente de aqua y estos habitaciónes son demasiadamente importante para aves, mamíferos pequeños, venados oreja de mula del desierto, y otros silvestres del desierto. Peces, algunos raro y en riesgro de vida, se hallan en los ríos mayores y en algunas cienagas apoyo de aquas de fuente.

Excepto en Tejas, la mayor parte de desierto es del govierno Federal. Dominio particular es el caso al rededor de centros de población y terras agricultural y irrigadas. Minería y ganadería son los principal usos economicos del desierto.

El crecimentro de población en los desiertos apresuró durante la Guerra Mundial II, a medida de dilatar las industrias defensas y facilitades militarias de instrucción. Inviernos y veranos temperados por acondicionamiento del aire inducién comercios, instalaciones defensas y militarias, y individuos. Turismo, minería, instalaciones defensas y militarias, alta tecnología, industria, y construcción provenen empleos para el crecimento de trabajadores. Retirados, tambien, se estan mudando para la zona del sol en creciente multitud.

La creciente población humano estan haciendo demandas nuevas del desierto. Extenso recreación, includendo excursión a pie, partidas de campo, boscá de rocas, fotografía, cazar sylvestres, y manejo de vehiculos deviados del camino principal, en conjunción de ganadería, a resultado en conflictos de vario grados. Demandas, tambien, estan subiendo para mineriá, habitaciónes, sitios de industria, nuclear y central eléctrica de fuerza geotermal, campos de energiá solar, y corredores para transportación y transmissión de fuerza eléctrica.

La sistemas ecologícas del desierto son frágil y restablan muy despacio despues de disturbio. La vegetación del desierto es frecuentemente destruída abajo la presión de satisfacer necesidades de termino corto, y la erosión avanza al punto de no retorno. Claro, el desafío es hacer frente las demandas esencial de público por lugares para vivir, trabajar y jugar, para aire limpio, y suficiente provisiones de aqua y energía sin de mas deterioración y restituir habitaciónes ya deterioradas. Para hacer frente estos desafíos exigirá nuestro mejor pensamiento y diplomacia.

Aprovechamiento de Algunos Recursos Forestales de Zonas Aridas en México.[1]

Ing. Eliseo Niño Velazquez y Ing. Enrique Patiño Ochoa[2]

Resumen.-- Se proporciona información resumida sobre la importancia, la distribución y la utilización del "guayule", de plantas productoras de fibra ("lechuguilla" y "palma zamandoca") y de "jojoba", con relación a las zonas áridas de México.

GUAYULE

El guayule es un arbusto que en condiciones naturales crece silvestre en regiones semidesérticas. Es nativo de las zonas áridas del norte de México, encontrándose tambien en el "Big Bend" y en áreas adyacentes en Texas en los Estados Unidos, prolifera comúnmente en altitudes de 1800 a 2100 metros s.n.m.

En su habitat, crece en manchones dispersos; se encuentra en regiones con precipitación pluvial de 150 a 450 mm. al año. Se estima que la planta llega a vivir hasta 30 años o más.

En México, cubre una superficie aproximada de 30 millones de hectáreas que comprenden parte de los Estados de: Coahuila, Durango, Chihuahua, Zacatecas-Nuevo León y San Luis Potosí.

Estudios realizados por la Comisión Nacional de Zonas Aridas, indican que la densidad promedio es de 1.2 toneladas de arbusto explotable, que, con un contenido de hule de alrededor del 12% significan un potencial de más de 30 000 toneladas anuales de hule natural.

Se estima que el guayule total explotable en el país, es del orden de 2.6 millones de toneladas de arbusto. Es posible establecer una corta anual de 313 325 toneladas anuales proveniente de las regiones donde su población presenta una dispersión adecuada para su explotación.

Se ha comprobado que el guayule es susceptible de ser cultivado, habiéndose obtenido en Estados Unidos, híbridos de un mejor desarrollo.

En México, la explotación industrial del guayule data de 1902, año en que el Gobierno otorgó concesión a una empresa de Estados Unidos, la cual instaló en San Luis Potosí la primera planta extractora de hule de guayule, y a la que siguiera otras plantas en los Estados de Coahuila, Durango y Zacatecas, estimándose que para 1911, había una inversión de 30 millones de pesos.

Durante la segunda guerra mundial, en un período de 6 años, se cortaron en México un total de 120 000 toneladas de guayule para atender necesidades de hule natural de los Estados Unidos.

Al término de la guerra y por problemas de competividad en el mercado, el producto perdió demanda, cerraron las plantas productoras y se suspendió la explotación del guayule hacia el año de 1947.

Composición de la planta de guayule

Componente	%
TOTAL	100.00
Hojas	4.00
Hule	11.52
Resinas	2.88
Otros (Corcho y celulosa)	61.60
Agua	20.00

[1]Trabajo presentado en la Reunión de Inventarios de Recursos de Tierras Aridas, La Paz, México, Noviembre 30 - Diciembre 6, 1980.

[2]Asociación Mexicana de Profesionales Forestales, A.C.

Las zonas áridas de México se caracterizan por una situación de depresión económica y social. Explorar las posibilidades amplias del aprovechamiento de sus recursos forestales, debe ser una acción de gran importancia regional pues resulta urgente e inaplazable mejorar las condiciones de vida de los habitantes de las zonas áridas, propiciando fuentes de trabajo adecuadas a su cultura para asegurar su eficiencia.

Por cada 5 000 toneladas de hule que se produzca se pueden crear 1 150 empleos, de los cuales el 85% serán de campo.

LECHUGUILLA, PALMA ZAMANDOCA Y OTROS

La zona ixtlera tiene una extensión territorial de 20 millones de hectáreas, aproximadamente la décima parte de la superficie del Territorio Nacional. Abarca gran parte del Estado de Coahuila, el sureste de Nuevo León, el noreste de Zacatecas, el noreste de San Luis Potosí y el suroeste de Tamaulipas.

Clima y Vegetación

El clima de la región es desértico y semidesértico, su principal característica la constituye la escasez e irregularidad de las precipitaciones pluviales, a excepción de Tamaulipas y parte de la Sierra Madre Oriental que cuentan con climas semi-húmedos y más regulares, y por lo mismo puede encontrarse vegetación sabana, pradera y bosque mixto.

Como consecuencia del tipo de clima predominante, carece de ríos y cuenta únicamente con corrientes intermitentes, que se forman sólo en época de lluvias. Lo anterior, destaca la importancia de los jagüeyes, único modo de conservar el agua. Dentro de la vegetación se encuentran: el mezquite, el huizache, la candelilla, la gobernadora, las cactáceas y los agaves, dentro de estos dos últimos la palma zamandoca y la lechuguilla, cuya explotación proporciona parte de su ingreso al campesino ixtlero.

Población

En esta gran área geográfica, aproximadamente un millón de mexicanos viven diseminados y en pequeñas comunidades de menos de dos mil habitantes, localizadas en sitios no adecuados para el desarrollo de una población.

Las viviendas presentan diferentes características, construídas unas con adobe y otras con varas o palma. Las familias constan en promedio de 8 a 10 miembros, que se alimentan principalmente con maíz, frijol, chile; ocasionalmente arroz, huevo y más raramente con leche y carne.

Lógicamente, mal alimentados, son fácil presa de la desnutrición, parasitosis, tuberculosis y enfermedades gastrointestinales.

Actualmente, puede decirse que esta situación ha sufrido grandes transformaciones, y sin que signifique se han resuelto todos sus problemas, si se observa como en el período 1968-1975 se han realizado programas especiales de beneficio colectivo.

Dentro de la zona ixtlera del país, están ubicados 41 municipios que son los siguientes: Coahuila: (1) Parras, (2) Gral. Cepeda, (3) Saltillo, (4) Cuatro Ciénegas, (5) San Pedro de las Colinas (6) Arteaga, (7) Castaños, (8) Ramos Arizpe, (9) Ocampo. Nuevo León: (10) Aramberri, (11) Dr. Arroyo, (12) Mier y Noriega, (13) Zaragoza, (14) Iturbide, (15) Galeana, (16) Mina, (17) Rayones, (18) Villa de García, (19) Sta. Catarina. San Luis Potosí: (20) Cedral, (21) Matehuala, (22) Vanegas, (23) Villa de la Paz, (24) Villa de Guadalupe, (25) Estación Catorce, (26) Cerritos, (27) Ciudad del Maíz, (28) Charcas, (29) Venado, (31) Villa Hidalgo. Tamaulipas: (32) Bustamante, (33) Miquihuana, (34) Palmillas, (35) Tula, (36) Jaumave. Zacatecas: (37) Concepción del Oro, (38) Mazapil, (39) Melchor Ocampo, (40) San Salvador, (41) Villa de Coss.

Origen, Recolección y Tallado

La recolección de las fibras de palma y lechuguilla, plantas que crecen silvestres en el semidesierto mexicano, se realiza en una forma bastante primitiva, ya que los talladores con instrumentos que no han mejorado técnicamente desde hace muchas décadas y su labor es individual, tanto en el corte de la penca como en su tallado. Los campesinos talladores salen a recolectarla solos o en pequeños grupos, a veces llevando a sus hijos varones que están en condiciones de ayudarlos, caminando varios días fuera de su hogar.

La parte de la planta que recolectan se llama "cogollo" o "puya" (pencas centrales) con el llamado "cortador", "trazador" o "mula", al que proceden a tallarlo con el "tallador", la "estaca" o "apoyo" y el "bolillo", logrado ésto lo amarran en manojos y lo llevan a las cooperativas. En una jornada diaria de ocho horas, un campesino talla un promedio de 5 a 8 kilogramos de ixtle.

En 1968, se pagaba al campesino con vales, la fibra de palma a un peso ochenta centavos. Actualmente, se paga en efectivo (erradicándose la tienda de raya) a tres pesos y siete pesos, respectivamente (seis pesos precio de adelanto y treinta centavos de remanente).

El ixtle de palma zamandoca y lechuguilla se recolecta manualmente por los campesinos. La fibra obtenida por el tallador ixtlero se le compra y paga oportunamente.

IXTLE DE LECHUGUILLA

Desde el siglo pasado, la recolección y el tallado de ixtle de lechuguilla, ha constituído uno de los pilares de la economía de millares de campesinos de la región desértica del país, debido a lo aleatorio de las cosechas agrícolas, a menudo, se convierte en la única fuente generadora de ingresos para la gente de esta región.

La institución de los campesinos ixtleros, tiene como objetivo principal asegurar la compra de fibra recolectada y tallada por los cooperativistas agrupados en su seno, otorgando un precio de garantía por kilogramo de ixtle tallado y recopilado en la zona del productor, para posteriormente, beneficiarla, en sus unidades fabriles y colocarla en el mercado nacional e internacional.

La Forestal, F.C.L., cuenta con cinco factorías beneficiadores del ixtle de lechuguilla en los Estados de Coahuila, Nuevo León y San Luis Potosí; la fibra es transformada en carés, colas, tapetes y maraña y no obstante la fuerte competencia de otras fibras naturales y sintéticas, la actual administración mantiene las fábricas en condiciones óptimas de producción, siguiendo el objetivo de la política económica del régimen federal de alcanzar la industrialización total de los productos del campo.

El ixtle de lechuguilla, además de lo anterior, coadyuva a equilibrar la balanza comercial del país por los ingresos de divisas que genera por concepto de su exportación, y sus Unidades Fabriles son fuente de trabajo para numerosos obreros.

IXTLE DE PALMA ZAMANDOCA

Al constituirse en 1940 La Forestal, F.C.L., no tenía como fin de su actividad el de intervenir en el comercio del ixtle de palma, pero el Gobierno Federal, ante la importancia económica que revestía la producción de esta fibra para numerosos ejidos de campesinos, se convirtió en comprador de la palma tallada, comprometiéndose a otorgar un precio de garantía y recopilarla en el campo del productor, y también distribuirla a los industriales que fabrican manufacturas con esta fibra. Los campesinos lechuguilleros que contribuyeron a la formación de la Forestal, F.C.L., sostienen que los palmeros deben cooperar en igual forma.

En el año de 1961, al comprar factorías a los industriales particulares, se inició el beneficio del ixtle de palma y la venta de sus productos terminados.

En la actualidad, se cuenta para la industrialización de la palma con una moderna planta situada en la Ciudad de Saltillo, Coah., en donde se refleja el interés de la actual Administración de incrementar y diversificar la producción de sus manufacturas, que además, de los tradicionales de cordelería, costales y telas de palma, se fabrican cortinas, tapices y otras manufacturas con mayor grado de elaboración. Se cuenta para la distribución de estas mercancías con agencias de ventas en toda la República Mexicana y con personal especializado en la búsqueda de nuevos mercados y consolidación de los antiguos.

JOJOBA

Ante la eminente necesidad de buscar nuevas fuentes de trabajo y elevar el potencial económico de zonas marginadas del país, como lo son las zonas áridas, se ha despertado el interés por conocer las especies productivas que crecen en dichas zonas, entre estas especies destaca la "jojoba" (Simmondsia chinensis) que es una planta desértica que se desarrolla y fructifica en forma natural en la región noroeste de México y Suroeste de los Estados Unidos.

Esta planta tiene bajos requerimientos de agua por lo tanto es muy resistente a la sequía; asimismo al desarrollar en zonas áridas muestra gran tolerancia a la concentración de sales que generalmente acompañan a los suelos y son característicos de estas zonas.

En las regiones desérticas se le ha reconocido desde hace mucho tiempo por su valor como planta forrajera, pero recientemente debido a sus cualidades se ha despertado el interés mundial en diversos aspectos.

La jojoba es la única fuente vegetal conocida en el mundo, en la que sus semillas contienen un aceite que es en realidad una cera líquida y no un aceite graso-

so, que al analizarse se le consideró así por tratarse de ésteres no glicéridos de cadena recta, cada uno de ellos de 20 a 22 átomos de carbono y una doble ligadura. Con esta sustancia se puede disminuir notablemente la caza del cachalote de esperma (especie en peligro de extinción) ya que la fuente tradicional de esta sustancia es la grasa de esta especie de ballena.

Esta cera líquida se encuentra aproximadamente en un 50% del peso de la semilla y es utilizada en la elaboración de lubricante de diversos tipos, ceras, linóleos, tintas de imprenta, velas, farmacopea, etc.

Descripción Botánica

Esta planta pertenece a la familia Buxaceae, y su nombre Simmondsia chinensis, basado en el primer nombre específico que se le dió a la planta, es el correcto botánicamente, aunque perpetua un error geográfico. Posee varios nombres vernáculos, entre ellos, Hahowi (el nombre indio original), jajobe baya de café, etc.

La jojoba, es un arbusto leñoso de color verde, con hojas opuestas con consistencia coriácea azul-verde, y sus frutos al madurar son café obscuro, parecido a una nuez. La semilla (cápsula) mide aproximadamente 2 cm. de largo y contiene una sola semilla.

Las flores masculinas (estaminada) y la femenina (pistilada) se desarrollan en plantas separadas.

Se han reportado casos de hermafroditismo contándose con algunas plantas de estas características en el campo experimental del I.N.I.F. de "Todos Santos" B.C. Sur.

Metodología del Cultivo

a) Epoca de siembra.- Se recomienda hacer la siembra en el vivero en los meses de abril y mayo para poder transplantar en mayo y junio, o bien en agosto y septiembre para transplantarse en septiembre y octubre respectivamente, con la finalidad de que la época de transplante no coincida con el invierno o con las altas temperaturas de verano, siendo mas crítico el primero.

b) Preparación del terreno.- El terreno debe ser nivelado, barbechado, rastreado y tabloneado, posteriormente se procede al surcado.

En terrenos pesados es recomendable dar un paso de subsuelador donde irá la línea de plantas con la finalidad de tener mayor penetración de agua y raices.

c) Transplante al huerto.- El transplante se realiza aproximadamente al mes y medio de hecha la siembra, donde se espera que la plantita tenga una altura de 5 centímetros y con un promedio de 8 hojas así como un buen desarrollo radicular. La distancia recomendada es de 1.50 m. entre planta y planta y separación entre surcos de 3.00 m.

d) Riegos.- (1) Por gravedad.- Se recomienda regar tan pronto sea posible después de hecha la plantación con una lámina de 10 cm. y 2 riegos posteriores con láminas de 5 cm. y con una frecuencia aproximada de 10 a 15 días. (2) Por goteo.- Por este método ya son conocidas las ventajas en otros cultivos y en éste en particular, debido a su instalación, se puede eliminar el vivero y consecuentemente el transplante, pues la siembra se hace directa en el campo.

e) Prácticas culturales.- Las prácticas culturales se enfocan principalmente a levantar surcos cuando éstos se vean deteriorados por el viento o por riegos, así como para el combate de malezas; en la actualidad no se han determinado enfermedades ni plagas que ameriten control químico para la jojoba.

f) Ramas y flores.- El crecimiento de ramas en la costa de Hermosillo presenta la máxima actividad en el mes de febrero y la menor actividad vegetativa en los meses de julio, agosto, noviembre, diciembre y enero.

Las ramas en general crecen un promedio de 30 cm. en un año.

La época de crecimiento de brotes laterales es la misma que la del crecimiento de brotes terminales.

La época de floración varía tanto de la misma planta como de una planta a otra, habiendo algunas que empiezan a florear desde diciembre; las yemas florales nacen tanto en brotes laterales como terminales, desde el mes de marzo hasta diciembre.

g) Cosecha.- La jojoba empieza a dar sus primeros frutos a los 3.5 años de edad, poco después de la diferenciación de sexos.

La recolección de semilla se hace manualmente al momento o un poco antes en que la cápsula empiece a abrirse.

La semilla de jojoba requiere un cuidado mínimo después de la cosecha y puede ser almacenada por largo tiempo sin detrimento de su calidad.

Métodos de Reproducción

Existen 2 tipos de reproducción los cuales son:

a) Reproducción Sexual
b) Reproducción Asexual

a) Reproducción Sexual.- En los trabajos realizados en México para la reproducción sexual, se eligen fenotipos de alta producción así como ecotipos diferentes para estudiar su adaptación bajo condiciones de temporal y de cultivo.

En general la semilla de jojoba presenta un alto porcentaje de germinación, que oscila de un 70% a 80%.

Para la reproducción de plantas sexuales se recomienda utilizar envases polietileno negro de 10 cm. de diámetro por 15 cm. de alto, ya que estas dimensiones representan un gran ahorro económico tanto en material, como para el establecimiento de una plantación.

Los almácigos son colocados sobre una base de cemento para evitar la penetración de raíces, así mismo evitar el daño de transplante del almácigo al envase ya que esta planta presenta un extraordinario desarrollo radicular. También se puede efectuar la siembra para la reproducción sexual en forma directa en el envase, colocando 3 semillas por envase para dar oportunidad a que cuando menos una de ellas sea femenina.

Las semillas se pueden obtener del recurso silvestre, y la época de recolección se recomienda en los meses de junio y julio.

b) Reproducción Asexual o Vegetativa.- La reproducción asexual de jojoba se puede hacer por 3 métodos que son:

1) Reproducción por estacas
2) Injertación
3) Cultivo de tejidos

1) Reproducción por estacas.- Se recomienda que las estacas utilizadas presenten 4 nudos y dichas estacas pueden ser tratadas con diferentes concentraciones de ácido indolbutírico (AIB) (15 a 20 mil p.p.m.) poniéndose en enraizamiento en una mezcla de turba y poliestireno.

2) Injertación.- Para este método se recomienda utilizar yemas de plantas jóvenes, y se han establecido experimentos con varetas de 2 a 3 mm. de diámetro y la longitud de 10 a 12 cm. y con patrones de 2 años.

3) Cultivo de tejidos.- Este método es el mas moderno per a la vez el más costoso, se realiza con tejidos merismáticos.

Usos

La jojoba presenta muy diversos usos como son:

Lubricación.- Es el único aceite que opera en la lubricación de maquinaria, resistiendo altas temperaturas y presiones. Se utiliza en la lubricación de maquinaria de precisión. Sirve muy bien como aceite de pulidora o como aditivo para otros lubricantes, y puede utilizarse como aceite transformador.

Cosméticos.- Uso presente como aceite para el pelo, champú y jabón. Uso potencial en cremas y productos para el bronceado.

Farmacopea.- Portador o cubierta de algunas preparaciones medicinales. Estabilizador de productos de penicilina. Inhibidor del crecimiento del bacilo tuberculoso. Potencialmente para el tratamiento del acné. Histórico uso como restaurador del pelo.

Alimentación.- Aceite de cocinar, aditivo de bajas calorías para aderezos de ensaladas, aceite vegetal, manteca.

Alcohol y derivados de ácido.- Preparación de desinfectantes, detergentes, lubricantes, secadores, emulsificadores, resinas plásticas, capas protectoras, fibras, inhibidor de corrosión y bases para cremas y pomadas.

Cera hidrogenada (sólida).- Ceras pulidoras para pisos, muebles y automóviles. Capas protectoras en frutas, preparación de comidas y objetos de papel. Para pintura de labios. Fabricación de velas que se queman con brillantez y sin humo, alto punto de fusión. Encoladoras para productos marinos.

Aceite extraído de la harina.- Es un suplemento de la alimentación animal, con 30-35% de proteínas. Uso potencial en fertilizantes, si se utiliza el alto contenido de nitrógeno.

Cáscara de la semilla.- Sirve como "mulch" mejorador del suelo; usándolo como cubierta protege al suelo de la evaporación, erosión y malas hierbas.

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SUMMARY

Information is provided relative to the importance, distribution, and utilization of guayule, some fiber producers (lechuguilla and palma zamandoca) and jojoba in Mexican arid lands.

Seccion II. El Reto en Materia de Inventario en Zonas Aridas — Una Panorámica[1]

Section II Arid Land Inventory Challenges — An Overview[1]

Ing. Raul Villareal C.[2]

El próposito inicial es encontrar las formas más variables para conocer los recursos de las zonas áridas y en base a este conocimiento alcanzar metas superiores. Definir que necesidades de información y cuáles son los problemas que hay para obtenerla, comprender que estas zonas no constituyen un solo ecosistema sino un conjunto de pequeñas, que por su fragilidad deben ser comprendidas cabalmente, para evitar su destrucción.

Deseo agradecer a los organizadores del evento "Inventarios de Zonas Aridas" el haberme distinguido al invitarme a presidir la Sección II del mismo, y que tiene como tema central, el desafío que tiene el hombre para realizar inventarios de recursos naturales acordes con las necesidades que tienen las zonas áridas.

Como todos ustedes saben, las principales zonas áridas del mundo, se distribuyen a lo largo de dos cinturones que pasan por los trópicos de Cáncer y Capricornio, respectivamente. Comprenden una superficie del orden de 20 millones de Km2, equivalentes a 14% de la superficie total del planeta.

En México, existen 56 millones de los de zonas áridas y 23 de semiáridas, las que sumadas equivalen al 40% de la superficie total del país y en ella viven más de 10 millones de personas.

Aunque los desiertos se consideraban como áreas deshabitadas, la explosión demográfica se ha dejado sentir en ellas, existiendo una densidad de población, para las zonas áridas y semiáridas en México, varía de 6 a 90 habitantes por Km2, con una media de 11.

Las necesidades alimenticias y la demanda de contar con fuentes de trabajo más numerosas, ha dado origen a que la importancia que se otorga a la zona árida y a sus recursos naturales sea cada vez más grandes, sin embargo para que alcancen su verdadero potencial será preciso contar con técnicos y metodologías que hagan posible elevar la productividad regional; Conocimientos que solo podrán adquirir a través de investigaciones orientadas hacía la determinación de qué recursos y en qué forma pueden aprovecharse.

La explosión demográfica ha impactado considerablemente a los recursos naturales, debido a las necesidades crecientes, que originan la destrucción de la biomasa en grandes superficies, el avance acelerado de la erosión, el abatimiento de los mantos freaticos, la destrucción de las cuencas hidrológicas, y la degradación de las poblaciones naturales, debido a explotaciones no adecuadas.

Paradojicamente, nos encontramos que muchas de las soluciones propuestas para resolver los problemas que afectan a los desiertos, en lugar de actuar en sentido positivo, han dado lugar a situaciones más conflictivas, debidas a que la ignorancia del hombre al aprovechar el desierto, no le ha permitido vislumbrar las consecuencias que producen cuando existe una acción antropogénica.

Fortaleciendo la aseveración anterior, se puede señalar que no basta con dispo-

[1] Trabajo presentado en el Evento Internacional, "Inventarios de Recursos de Zonas Aridas", La Paz, B.C.S., México, Nov. 30-Dic. 6, 1980.

[2] Ing. Agronomo Especialista en Bosques, Instituto Nacional de Investigaciones Forestales, México.

ner de agua suficiente para hacer del desierto un vergel, ya que si solo se considera este factor, sería desconocer el fondo del problema; también será preciso considerar otros muchos factores como:

Intensidad de la luz solar, cuantía y característica de los vientos, tipo de suelos, etc.

Por lo anterior, es que no basta con tener un conocimiento cualitativo y cuantitativo de la vegetacion, sino además se precisa conocer las interacciones entre factores físicos y abióticos como:

Geología, Geografía, clima de suelos y los factores bióticos: Vegetación, fauna, ganadería y hombre, todo ello analizado como un todo para determinar el uso y el manejo más eficiente, en base a un aprovechamiento optimizado y persistente.

Es menester comprender que las zonas áridas no contituyen un solo ecosistema, sino el conjunto de muchos pequeños, que por su fragilidad deben ser comprendidos cabalmente, para evitar su destrucción.

A pesar de las condiciones tan extremosas que prevalecen en los desiertos existe una gran variedad de flora y fauna, tan solo en el Valle de la Muerte en California vegetan más de 600 especies, además de otros recursos como agua y yacimientos minerales.

Estos valiosos recursos, pueden ser la base para incorporar a la producción, pero nuestro reto, nuestro desafío consiste en lograr el manejo racional de agua, suelo y planta, y de ahí aumentar la producción, especialmente la alimenticia, para cambiar los esquemas socioeconómicos prevalecentes, que son tipicamente de subsistencia por otros caracterizados por alta productividad.

Como parte inicial de este propósito, y como razón de este evento, es el encontrar las formas más variables para conocer los recursos de las zonas áridas y en base a este conocimiento alcanzar metas superiores.

Es en esta Sección donde se tratará de definir que necesidades de información y cuales son los problemas que hay para obtenerla.

En tal virtud se hanregistrado 17 diferentes trabajos, en los que se discutirán aspectos específicos sobre diversos temas.

El tema subdividido en dos paneles, en el primero se plantearán situaciones sobre los siguientes tópicos:

1. Políticos y desarrollo de programas.
2. Planeación en el uso de la tierra en Zonas aridas.
3. Inventario de recursos en suelos áridos
4. Información sobre requerimientos para evaluar las interacciones entre la fauna y el ganado.
5. Bases analísticas para integrar inventarios forestales y de suelos de uso pecuario.
6. Información sobre recursos renovables necesarios para el desarrollo minero en zonas áridas.
7. Necesidades de información climática para el eficiente manejo de terrenos áridos.

En el segundo Pánel se abordarán los siguientes temas:

1. Problemas legisticos en inventarios tropicales.
2. Técnicas para medición.
3. Costos benéficos.
4. Cambio de recursos.
5. Homogeneización, coordinación y cooperación entre actividades de los recursos
6. Homogeneización, coordinación y cooperación entre agencias de recursos.

Seguramente, los planteamientos y las discusiones que se deriven de ellos, conducirán a un mejor conocimiento de los "Inventarios sobre Zonas Aridas".

ABSTRACT

The initial purpose for this study is to find varied ways to determine the resources of the arid zones, and, with this knowledge, reach for higher goals. Additional goals are to define which are the informational needs and how these can be met, and to understand that these zones do not constitute just one ecosystem but are a composite of many smaller ones which, due to their fragile nature, should be fully understood in order to prevent their destruction.

PANEL A

Policy and Program Development[1]

George D. Lea[2]

Inventory requirements of the Federal Land Policy and Management Act of 1976 has caused the Bureau of Land Management to revise its inventory policies and to intensify its inventory coordination efforts. The major elements of this program are establishment of criteria; specific coordination techniques or tools to facilitate inventory processes; and specifically identified points in the decisionmaking process where the tools are to be used.

The policy and program ramifications of arid land resource inventories are of critical concern to the Bureau of Land Management and I appreciate the opportunity to discuss the issues we have encountered in this area and the policies and procedures we are implementing to address these issues. It is indeed appropriate to hold such a workshop with our Mexican friends. We share a common arid zone of 300 million acres. An area not only substantial in size but containing natural resource values of national and international importance.

BLM is the largest public land manager in the U.S. We are responsible for management of 170 million acres, 140 million acres of which are arid. Therefore, BLM has a lot of responsibility and a lot at stake in arid land inventories. We have been conducting inventories of various intensity since 1930, but with the enactment of the Federal Land Policy and Management Act of 1976 (FLPMA) the Bureau has been required by law to prepare an inventory of all public lands, their resources and values, on a continuing basis. Since a significant portion of this responsibility encompasses arid lands, the BLM is keenly aware of the issues we will cover in this workshop and we are interested in learning from the experiences of others. We don't have all the answers.

Of most interest to you probably are the steps the Bureau has taken to establish policies to manage the inventory for our arid lands. We will be spending approximately $50 million on inventories and inventory program management in our current and subsequent fiscal years. One of our central concerns is that these expenses prove worthwhile to the Bureau and useful in its decisionmaking and land use planning processes. You must be aware that inventory and planning are not too well liked by some Members of Congress and OMB. So if BLM is to continue inventories at our current level, we must demonstrate to OMB that we are managing it effectively.

Initially, we reviewed our existing policies for managing inventories to determine if they were effective. This review concluded that we had some basic problems. They were (1st) lack of comprehensive analysis <u>prior</u> to beginning inventory programs. The result was often a failure to tailor the inventory process itself to deal effectively with the issues and problems needing examination; (2nd) lack of adequate standards for the data collected and the existence of inconsistent standards between Federal, State and local agencies preventing exchange or full use of inventory data; (3rd) lack of a systematic effort to equitably allocate the limited financial resources available for inventory; (4th) finally, we had a concern over the relationship between the cost of inventories in a limited budget and the impact of inventory data on the quality of the decisions resulting from the level of data our limited dollars could buy.

These findings convinced us that we needed to reexamine our policies and to establish, as a beginning, an inventory coordination function in our Headquarters Office. The charge of this office is to provide leadership in the design, development, implementation, and management of a Bureauwide inventory coordination strategy that will solve the problems I just outlined by providing inventory data satisfactory for our operational and land use planning needs. These needs are often quite distinct from inventory data applicable to research programs.

The <u>goals</u> of our inventory management function are four-fold:

1st. To ensure that land and resource inventory processes and programs are structured, implemented, and coordinated in a manner that will meet legislative and policy requirements and provide decisionmakers with the information necessary to make sound land use decisions.

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[1] Paper presented at the international workshop, Arid Land Resource Inventories: Developing Cost-Efficient Methods, Nov. 30 - Dec. 6, 1980, La Paz, Mexico.

[2] Deputy Director for Lands and Resources, Bureau of Land Management, U.S. Department of the Interior, Washington, D.C.

2nd. To ensure that land and resource inventory processes and programs are efficient and effective as possible given the relationships between the value of the land and its resources, the issues involved, and the risks associated with a lack of inventory data or incomplete data.

3rd. To ensure appropriate consistency and compatibility of land and resource inventory data across program and organizational unit lines.

4th. To ensure appropriate coordination and consistency between BLM inventories and those of other Federal, State and local governments.

In order to achieve these goals we have, over the past several months, developed a framework for our inventory coordination strategy. We have evolved these concepts through close collaboration with our resource specialty program offices.

This framework includes three major elements: (1st) a well developed inventory policy and criteria to help answer the questions of how much data is enough data, (2nd) specific coordination techniques or "tools," to facilitate inventory processes and (3rd) identification of specific points in the Bureau's decisionmaking process where the tools will be used. The first element of inventory policy and criteria requires the development of general policy along with criteria for each program area (i.e., for wildlife, soils, cultural and range). This policy and criteria will provide the appropriate degree of Headquarter's guidance for field use in making inventory decisions at critical program decision points. Policy and criteria is especially needed to help address questions such as:

1. How much data gathering is enough for decisionmaking in specific legal, management, fiscal, and adverse impact situations?

2. How much legal and management risk are involved at different levels of data collection and what is the appropriate trade-off point between anticipated risk and projected data collection cost?

The second element involves development of inventory coordination tools. Essential inventory coordination tools, tools that would force through analysis prior to commencing an inventory project, these include:

A. A common data element dictionary, used for all Bureau inventory processes and programs, and

B. Standard terminology, standard classifications, and compatible data measurement processes to ensure consistency between similar data elements.

This concept is not new. Many land management agencies including BLM already have programs for Information Systems Management which require standard data elements for ADP supported systems. Utilizing this strategy for our inventory program will reinforce this concept and achieve standardization of all of our inventory data - regardless of the data management vehicles (automated, manual or a combination of both).

The next element involves identifying the specific decision points where inventory coordination policy, criteria, and tools need to be applied by decisionmakers. We have identified the following critical decision points:

1st. <u>Planning Criteria</u>. These criteria are prepared before the planning process formally starts and are based, among other things, on the specific issues surfaced by the <u>public</u> for the area being planned.

2nd. <u>Preplanning Inventory Needs Assessment</u>. This occurs before the planning effort starts and is the first application of inventory policy and criteria to the situation.

Although these two decision points may seem basic they can often be bypassed and many times inventories begin without adequate thought given to matching the level of inventory to the specific issues to be faced into managing a land area.

3rd. <u>Acquisition of Materials</u>. Photos, Landsat, etc.

4th. <u>Decision Point is the Development of Budget Needs</u>. These decisions are based largely on findings from the preplanning inventory needs assessment.

As for inventory programs for other than land use planning, the same standards used above can be used.

We are also making progress in expanding our coordination of inventories at the interagency level through an Interagency Agreement on the Classifications and Inventories of Natural Resources. The members of this agreement are the Soil Conservation Service, the Forest Service, the Fish and Wildlife Service, the Geological Survey and the Bureau of Land Management. In fact, one of the members of this agreement will be speaking at tomorrow morning's first session under Section III, Panel B: Dan Merkel of the U.S. Soil and Conservation Service. I recommend that you hear Dan's paper to learn of a "success story" between five U.S. Federal Agencies.

We are also making good progress in evaluating the effectiveness of new remote sensing technology. We need to know which technology has advanced to the point where it can become operational. ASVT on Tuesday by Bonner is the results.

<u>Now I would like to return to a more detailed discussion</u> of the inventory coordination tools we are developing which are the "nuts and bolts" of our effort.

Central to our program are our definitions of standard levels of inventory detail. These establish a framework of detail levels which characterize the intensity of an inventory. The levels are used to guide inventory development and require that all inventory procedures be tailored to a specific level. The different levels (or sublevels) we are using (5 levels) constitute the choices available to field office staffs to match inventory intensity to the problems and issues involved in the area to be inventoried. Each level, for each resource, will have a common set of criteria, techniques for conducting the inventory, cost data, etc. Finally, adherence to the levels will ensure consistency in inventory processes and provide a better predictability and understanding of the inventory reliability achieved with a given procedure. Establishing and resolving different levels of inventory will be difficult. Each Resource Specialist wants to conduct the most intensive level in all cases and are reluctant to describe a less than ultimate level.

The stratification technique is not new, having been a key part of some inventory techniques for years. We propose to use it more systematically across all Bureau inventory processes.

These inventory levels range in complexity from those which will support regional and national requirements for data to the more site specific data and information requirements needed to support land use planning, activity, and management plans at the working level.

Our next coordination tool is to organize the various types of inventory procedures into groups with common characteristics and natural relationships.

Establishing these subgroups recognizes that inventory data needs are so diverse that a single integrated inventory is neither realistic nor practical. The groups we are using are: (1) natural resources; (2) heritage or cultural resources; and (3) geologic and subsurface resources.

The items I have just discussed comprise the tools and standards we have developed for Bureau inventories.

Our next step is to develop methods for translating these tools and standards into program applications. The first of these efforts is the development of a catalogue of inventory processes for the Bureau.

The catalogue includes a brief abstract of each inventory process, its utility, and an explanation of data elements, inventory level(s), standard data groups involved, and names of appropriate office or staff to be consulted on technical application of the process. We are currently using over 60 different and distinct inventory processes.

In support of the inventory catalogue, we are developing a handbook which will discuss the technical criteria for each of the inventory detail levels that the Bureau intends to identify. This handbook will, in other words, provide guidance on the appropriate technical criteria for inventories needed to respond adequately to whatever policy issue or decisionmaking situation generates the inventory need.

In a typical BLM District, the job of Inventory Management has become quite involved with many resources requiring data collection needed for management decisions and we find an Inventory Management position may be needed. This position will ensure that our inventory policies can actually be put into practice and that the data needed to monitor the effectiveness of our management decisions is evaluated and analyzed.

With the strategy I have described, the standards and tools we have developed and the techniques for program application we have defined, we anticipate both an inventory policy and resulting programs which will enhance our capability to manage our varied land base in a cost effective manner.

In Summary

Judging from our experience in BLM, I would identify three critical steps to the implementation of an inventory policy and development of an inventory program. A comprehensive inventory program must be responsive to mandates established by legislation and effectively support the internal management needs of the institution while dealing effectively with the uniqueness and variety of resources being inventoried. The first step is careful definition of the mandate which establishes or governs inventory processes. The second is a careful analysis of the existing situation so that previous problem areas and failures can be addressed in establishing an inventory policy. The third step is the development of consistent criteria, tools, and standards which can be applied to all kinds of inventory needs. These steps will not necessarily insure a successful inventory program but they will provide a logical framework on which to build the organizational capacity necessary to effectively collect and utilize inventories and establish measures with which to evaluate program success all in a cost-effective manner.

RESUMEN

Los requisitos de inventario de la Ley Federal para la Administración y Manejo de Tierras de 1976 han obligado al Negociado de Manejo de Tierras a revisar su política inventorial y a intensificar sus esfuerzos para la coordinación de inventarios. Los elementos principales en este programa son los siguientes: establecimiento de criterios, instrumentos o técnicas específicas de coordinación para facilitar losprocesos de inventario, y específicmente, puntos identificados en el proceso de hacer decisiones donde se han de usar los instrumentos.

La Planeación del Uso del Suelo en las Zonas Aridas.[1]

Ing. Heriberto Parra Hake.[2]

Resumen.-Las zonas áridas presentan muy diversas situaciones que resultan en característicos problemas básicos. Para lograr el desarrollo de esta zonas, es urgente conocer profusamente el territorio, contar con inventarios de los recursos naturales y conocer el potencial de los mismos: la información antes mencionada permitirá la adecuada planeacion del uso del suelo.

I.INTRODUCCION

Al través de milenios, el hombre ha sobrevivido sobre la faz de la tierra, fincando sus más importantes núcleos de población en donde encontraba sus principales satisfactores, el agua, la flora y la fauna. Posteriormente con el devenir de la historia del hombre, se desarrolló una agricultura y un pastoreo cuyo impacto en el medio ambiente no era negativo por su pequeña escala y características particulares; sin embargo, el desarrollo de las diversas culturas humanas siguió normalmente un patrón arbitrario y desorganizado en la planeación de sus comunidades y del uso de sus recursos, lo cual nos orilla en nuestros días, a buscar nuevas tierras con fuentes de abastecimiento y aprovechar las experiencias de los grandes errores cometidos en la antiguedad.

El acelerado avance tecnológico de las últimas décadas y el alarmante incremento de la población mundial, están propiciando, cada vez con mayor frecuencia, crisis en los renglones alimentario y de energéticos.

Esta creciente demanda de satisfactores está obligando a la humanidad, a valorar y acrear del potencial que representan los recursos naturales para la sobrevivencia futura del género humano y a buscar otras alternativas.

[1] Papel presentado en la Primera Reunión de Inventarios de Recursos de Tierras Aridas. (La Paz, B.C.S., México. Noviembre 30-Diciembre 6,1980).

[2] Director del Centro de Investigaciones Forestales del Noroeste.INIF-SFF-SARH.

Es en base a lo antes mencionado, que en los últimos años la comunidad mundial ha mostrado un creciente interés por las zonas áridas y una mayor preocupación por los procesos de desertificación, sus causas y las consecuencias socioeconómicas que se derivan a las comunidades de esta zonas áridas y las áreas aledañas que están siendo o pudieran ser absorbidas por las mismas, Este interés por las zonas áridas, se fundamenta en sus grandes extensiones relativamente vírgenes y el valioso potencial de sus recursos naturales prácticamente desconocidos y poco explotados. El interés en la desertificación, porque esas superficies antes fértiles y productivas se van perdiendo irremediablemente por un mal uso del suelo, reduciendo aún más la ya insuficiente superficie productiva de la tierra.

Es por ello importante al pretender desarrollar las zonas áridas, conocer profundamente sus recursos y la capacidad de uso del suelo, para de esta forma, con toda la información necesaria, se realice una adecuada planeación de las actividades productivas de esas regiones.

II.ANTECEDENTES

Actualmente el 43% de la cubierta emergente de la tierra corresponde a desiertos y zonas áridas contiguas, en una superficie de 37,600,000 Km2. Estas áreas están distribuídas en más de las dos terceras partes de los 150 países del mundo y en ella viven 628 millones de personas.

México ocupa una superficie aproximada de 2.000,000 de Km2 , presentando condiciones de aridez y semiaridez en 800,000 Km2 que representan el 40% del territorio nacional y donde viven aproximadamente 10 millones de -

de personas que representan un 16% de la población de la República. La densidad media por Km2 es de 11 personas, existiendo amplias regiones con 2 o más habitantes por Km2 y otras con 80 a 90.

Aunque el hombre ha vivido en aridez "Natural" y desertificación desde hace milenios, las zonas áridas actuales presentan muy diversas situaciones que no se refieren exclusivamente a las condiciones climáticas o medio ambientales, sino también y en forma especial a las socioeconómicas, legales y políticas.

Debido a esta gran diversidad de situaciones, se presentan enumerables problemas básicos que son característicos de estas zonas, tales como nomadismo, sobrepoblación, sobre pastoreo que incrementa la erosión y respecto a las prácticas de irrigación se puede mencionar, la regulación del agua, salinidad, deterioro del suelo, etc.

La historia del uso del suelo en estas reriones nos muestra lo precario de la vida y la fragilidad del medio ambiente árido; por lo tanto deberá tenerse mucho cuidado, aprovechando la experiencia de algunos grandes errores cometidos con anterioridad y evitarlos en la planeación del uso del suelo.

Por razones prácticas, las zonas áridas han sido comparativamente menos exploradas que aquellas con mayores densidades de población; sin embargo, el principal requisito para desarrollar esas zonas, será conocer profusamente su territorio y la potencialidad de sus recursos.

En México se han presentado diversas dificultades para planear el uso del suelo, entre otros se pueden mencionar el desconocimiento de los recursos naturales, reformas administrativas, duplicidad de funciones en diversos organismos y falta de coordinación a niveles operativos.

Con la finalidad de tener un marco de referencia de las condiciones actuales de los recursos naturales del país de uniformar las acciones encaminadas a ese objetivo, se creó el organismo "Comisión de Estudios del Territorio Nacional y Planeación", quienes para lograr una adecuada planeación del uso del suelo, han necesitado delimitar áreas en las cuales la interación de los elementos del medio físico y biótico se presentan sensiblemente de manera homogénea, lo cual hace suponer que dichas áreas tendrán el mismo potencial de uso y por ende, el manejo y aprovechamiento deberán ser semejantes. La información necesaria para esa zonificación, de una manera general considera como básicos los siguientes conceptos:

a).- Situación geográfica
b).- Topografía
c).- Climatología
d).- Hidrología
e).- Geología
f).- Suelo
g).- Vegetación
h).- Agricultura
i).- Ganadería
j).- Silvicultura
k).- Centros de población
l).- Infraestructura

La información antes mencionada delimitará un marco geográfico que permitirá elaborar una carta básica de la cual se pueda partir para hacer la planeación del uso de los recursos a nivel nacional, regional y local, apoyados en cartografía que realizan a tres diferentes escalas 1:1 millón, 1:250,000 y 1:50,000 las que consideran concluir en 1983.

Desafortunadamente por razones prioritarias, las zonas áridas serán las últimas en ser concluídas, aunque ya se llevan avances en diferentes escalas del centro al norte, parte del noreste y los estados de Baja California, Sonora y Sinaloa.

III.- NECESIDADES DE INFORMACION PARA LA PLANEACION DEL USO DEL SUELO.

En México aún cuando se han realizado esfuerzos para optimizar el uso del suelo en las zonas áridas y semi-áridas, éstos han sido escasos y aislados dándose prioridad a las zonas templadas con masas forestales importantes.

En basé a ésto, en la actualidad se carece de metodologías específicas para cuantificar y delimitar recursos y áreas para las diversas actividades humanas de estas zonas.

Dentro de las necesidades de información que se consideran de relevancia se mencionan las siguientes:

1.- Delimitación aprovechamiento de áreas con potencialidad agrícola y pecuaria.

En la antiguedad, el desarrollo de una zona agrícola o pecuaria se establecía a partir de un pequeño núcleo de familias interesadas en dicha actividad, con el tiempo estos asentamientos se espandían y las actividades se incrementaban haciendo un uso indiscriminado del suelo y de los recursos existentes, lo que ocasionaba en muchos de los casos serios problemas ya que el crecimiento desmedido, rompía con un equilibrio que necesariamente debe existir entre el hombre y el medio en el que habita.

Las necesidades de una población creciente demanda áreas cada vez mayores y tecnología más eficiente para la producción de alimentos; sin embargo, la apertura de nuevas áreas del cultivo deberá de fundamentarse con la informa

ción sobre el uso más adecuado del suelo para cada actividad en particular.

En forma específica, la península de Baja California demanda información con el objeto de definir áreas en las cuales las actividades pecuarias se desarrollen con mayor eficiencia ya que, no son escasos los ejemplos en los que se han seleccionado áreas para dicha actividad y los resultados para los objetivos que se fijaron dejaron mucho que desear, causando un gran deterioro ecológico en las zonas donde se establecieron; así mismo, la mala planificación debido a la falta de información en cuanto a la selección de las áreas abiertas al cultivoen diversas zonas, ha ocasionado el abandono de grandes extensiones de terrenos anteriormente productivos y que actualmente están afectadas por altas cantidades de sales ó en el peor de los casos, por el abatimiento total de los mantos freáticos; todo ésto debido a que no existe una planeación para la expansión de una zona agrícola en relación a la potencialidad de sus recursos hidráulicos.

2.- DE LOS RECURSOS FORESTALES.

Las zonas áridas y semi-áridas de México, cuentan con una gama de especies forestales con gran valor económico entre las que destacan : Candelilla (Euphorbia antisifilitica) ; Yuca (Yucca spp.); Lechuguilla (Agave lechuguilla); Jojoba (Simmondsia chinensis); por mencionar solo algunas de ellas; sin embargo, a la fecha son escasos los estudios que se tiene para cuantificar estos recursos, por lo que se requiere establecer metodologías específicas para su aprovechamiento o conservación ya que algunas especies podrán ponerse en peligro de extinción si se explotan sin tener información respecto a la cuantía de las mismas.

La agricultura tradicional de altos consumos de agua, deberá ser sustituída con la integración de nuevos cultivos seleccionados al través de un inventario de las especies forestales de importancia económica que vegetan en las zonas áridas.

Actualmente el Instituto Nacional de Investigaciones Forestales está realizando algunos trabajos de investigación para detectar y seleccionar las especies con potencialidad alimenticia, medicinal, industrial, ornamental, etc., al través de un Catálogo de Especies Utiles; no obstante, se requiere la base de información respecto a su cuantía para definirla, ya sea como una especie que pueda ser aprovechada en su forma natural, y hasta que punto este aprovechamientjo no atenta contra la especie o bien si es necesario inducirla al cultivo.

En general, para cuantificar el recurso vegetal es necesario conocer su superficie, su rendimiento por unidad de superficie y éste muchas veces será variable de una época a otra, de acuerdo a la bondad de las precipitaciones, o a otros factores como la presencia de heladas, etc. Factores de tipo físico como estos conllevan a un aspecto específico en cuanto a la planeación del uso del suelo: Es necesario regionalizar áreas en cuanto a producción, ya que si bien cierta especie tiene importancia económica y en condiciones silvestres puede ser redituable, no lo será necesariamente en toda su área de distribución, pudiendo en ciertas regiones, ser incosteable su aprovechamiento silvestre, pero posiblemente cultivándose presente redituabilidad satisfactoria.

3.- DE LOS RECURSOS DE LA FAUNA.

Los recursos faunísticos de las zonas áridas y semi-áridas de México, representan un renglón importante como elemento integrado del ecosistema, existiendo por una parte especies de gran valor económico, y por otra, especies que se encuentran en peligro de extinción; de las cuales podemos mencionar las siguientes : "Venado" (Odocoileus hemionus); "Berrendo" o "Antílope" (Antilocapra americana peninsulae); especie de animal que existió mucho en el Desierto de Vizcaíno en Baja California Sur, encontrándose hoy solo en número muy reducido por la caza inmoderada de que ha sido objeto. Su carne y su piel presentan posibilidades de explotación. El "borrego cimarrón" (Ovis canadensis) es una de las especies de mayor valor cinegetico, razón por la cual sus poblaciones son muy restringidas debido a la caza inmoderada.

Todo ésto, nos hace pensar en la necesidad de determinar mediante inventarios la clasificación del valor cinegético de tal o cual especie ó en su defecto mediante el fundamento de los inventarios legislar la preservación de la especie que en un momento determinado estuviese en peligro.

4.- DE LA RESERVA DE LA BIOSFERA.

El creciente desarrollo urbano determina una utilización cada vez mayor de superficie , lo que implica un impacto en los recursos bióticos, cuyos efectos en la mayoría de las veces han sido contraproducentes, todo ésto, debido a una falta de planificación del uso adecuado del suelo.

En base a lo anterior, se requiere contar con la información de todas aquellas zonas que debido a sus características de composición florística y faunística pudieran ser consideradas como reservas de la biósfera; a fín de legislar su establecimiento y conservar un acervo de los

recursos bióticos de la misma.

La península de Baja California, es uno - de los pocos ejemplos en el mundo, en los cuales la mano del hombre no ha intervenido notablemente, lo que ha permitido que actualmente se conserve casi intacta, no obstante por el crecimiento desarrollo económico para el que está desinada, es de vital importancia la protección y planificación de su aprovechamiento.

5.- DE POTENCIALIDADES TURISTICAS.

La optimización del suo del suelo implica una diversidad muy amplia de las actividades humanas entre ellas la recreación, grandes áreas actualmente permanecen improductivas por la falta de información de su potencialidad. En este caso particular, la recreación implica interrelación de factores económicos y sociales de gran trascendencia para el desarrollo de una zona. Las zonas áridas y semiáridas cuentan con atractivos para la emplementación de programas de inversión en este renglón, no obstante debido al equilibrio tan frágil que guardan éstos ecosistemas, se requiere que las áreas de recreación sean debidamente seleccionadas de acuerdo a la información derivada de los inventarios de uso potencial del suelo.

6.- PLANEACION DE LOS ASENTAMIENTOS HUMANOS.

Quizá uno de los aspectos de mayor importancia en cuanto a las necesidades de información para el adecuado uso del suelo sea el referente a los asentamientos humanos, ya que en estos ocurren todas las actividades humanas. El desarrollo urbano, las fuentes de abastecimiento, la planificación de una dasonomía urbana adecuada a las condiciones de aridez y los recursos del agua, deberán ser planteados sobre un marco de información de los recursos disponibles.

En la actualidad, la península de Baja California cuenta con um marcado incremento de población tanto en los extremos sur y norte debido a una mayor disponibilidad de agua y a las crecientes fuentes de trabajo, por lo que se hace necesario más información para una adecuada planificación de los futuros asentamientos humanos.

7.- SELECCION DE AREAS DE APROVECHAMIENTO DE NUEVAS FUENTES DE PRODUCTOS MINERALES Y ENERGIA TALES COMO SOLAR, EOLICA, GEOTERMICA Y PETROQUIMICA.

La península de Baja California y el estado de California en los Estado Unidos de Norteamérica, fueron reconocidos en el siglo pasado por su riqueza en algunos minerales entre los cuales destacó el oro; actualmente se han detectado zonas ricas en cobre, yeso, fosfatos y otros compuestos de gran valor comercial en los cuales a la fecha, no se han profundizado los estudios en cuanto a su cuantía y distribución a lo largo de la península.

Muchos yacimientos de metales valiosos permanecen improductivos debido a una falta de información al respecto.

El uso del suelo en las zonas áridas, deberán de contemplarse sobre un marco de uso múltiple de los recursos con que se cuenta. El aprovechamiento de fuentes de energía que contribuyan a proporcionarla en una forma más económica y eficaz, es uno de los objetivos que se han fijado para el desarrollo de actividades diversas en las zonas áridas. Existen fuentes de energía tales como la solar y eólica que representan una alternativa viable para dichas zonas; sin embargo para lograr un máximo aprovechamiento de esta energía, se requiere seleccionar las áreas idóneas para la implantación de grandes centrales generadoras de energía eléctrica, ya sea por el sistema solar, eólico o bien detectar áreas con potencialidad de aprovechamiento de la energía geotérmica. En los últimos años se han detectado yacimientos petroliferos que pueden convertirse en recursos básicos para la economía de la región.

8.- PLANEACION DE LA INFRAESTRUCTURA HIDRAULICA.

Los puntos anteriormente mencionados difícilmente se podrán lograr si no se cuenta con la disponibilidad de un recurso de vital importancia : El agua, elemento en el cual se basa el desarrollo de cualquier actividad humana y que en las zonas áridas y semi-áridas, cobra un especial interés.

En forma general en la península de Baja-California, las precipitaciones pluviales se presentan en forma torrencial y de corta duración, lo que ocasiona que se formen grandes afluentes que en un gran porcentaje se vierten en el mar.

Lo anterior evidencía la necesidad de contar con la base de información que proporcione en dónde, y en qué forma pudieran aprovecharse.

Por otra parte, el conocimiento de la calidad y tipo de suelo en cada zona podrá ser la base para la aplicación de diversos sistemas de riego, que determinaría una optimización del recurso agua. Finalmente, existen grandes perspectivas para un nuevo desarrollo tecnológico que en forma rentable pudiera proporcionar agua dulce a través de la destilación del-

agua del mar.

Como se puede apreciar, los inventarios de los recursos de zonas áridas son de capital importancia, para fundamentar y posteriormente optimizar cualquier actividad humana en el desarrollo, conservación e incremento de los recursos con que se cuenta.

IV.- CONCLUSIONES Y RECOMENDACIONES.

De todo lo tratado anteriormente se concluye que debido a la creciente explosión demográfica mundial, la necesidad de satisfactores es cada vez mayor, lo cual está orillando a buscar el desarrollo de las zonas áridas con el fín de aprovechar sus recursos.

De la misma forma queda claro que existe un marcado desconocimiento de estas zonas, lo cual requiere de trabajos tendientes a lograr el inventario de sus recursos naturales y de sus características particulares, deberá tenerse siempre en mente que el factor limitante para cualquier desarrollo es el agua y la fragilidad de los ecositemas; deberá también tomarse muy en consideración la peligrosa combinación suelos ligeros y lluvias torrenciales de corta duración que caracterizan a las zonas áridas.

Hasta que se cuente con toda la información requerida será posible finalmente lograr la planeación del uso del suelo que se recomienda considere la siguientes lineamientos:

1.- Determinar el uso más adecuado a cada área ya sea para agricultura, ganadería, explotación forestal, recreación, etc.

2.- Establecer lineamientos para elegir prácticas adecuadas para la explotación, conservación y protección de los recursos existentes.

3.- Fundamentar las bases para realizar trabajos de investigación y experimentación, así como la adecuada aplicación de los resultados obtenidos.

4.- Localizar las áreas ecológicamente más adecuadas para la creación de reservas de la biósfera, nuevos centros de población y zonas industriales.

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ABSTRACT

Arid zones exhibit very diverse situations which result in basic characteristic problems. In order to develop these zones, it is imperative to have a thorough knowledge of the area, to have at hand an inventory of the natural resources, and to know their potential. This information will allow for adequate planning of land utilization.

Necesidades de Información para la Planeación de Actividades[1]

Víctor E. Sosa Cedillo[2]

Resumen.--La información necesaria de los recursos de zonas áridas con fines de planeación, se demanda según los siguientes niveles: nacional o regional, de manejo y operaciones. Cada uno de estos niveles requiere de información cuantitativa y cualitativa, que sirve para lograr el adecuado aprovechamiento, protección y fomento de los recursos de las zonas áridas.

INTRODUCCION

El manejo adecuado de los recursos de las zonas áridas, requiere de información suficiente para planear correctamente las actividades a desarrollar. En el caso de México lo anterior es de gran importancia, dado que cerca de un 38% del país (75.5 millones de hectáreas), poseen vegetacion de zonas áridas o semiáridas, calculándose que el 16% de la población total habita en estas áreas, por lo que las acciones que se lleven a cabo son decisivas en las condiciones de vida de sus habitantes. La planeación de actividades se verifica a diferentes niveles, por lo cual las necesidades de información se pueden jerarquizar de acuerdo a los mismos, siendo el objetivo de este trabajo, describir en términos generales cuáles son estos rangos o grupos de información, con el propósito de facilitar los trabajos a desarrollar y la definición de responsabilidades de las diferentes instituciones que intervienen en las zonas áridas de México, buscando, como se indica en el tema de esta reunión, los métodos más eficientes en costos.

ANTECEDENTES

De acuerdo a datos del Inventario Forestal de México, la superficie del país cubierta por vegetación de zonas áridas y semiáridas es de 75.5 millones de hectáreas, de las cuales 29.2 millones de hectáreas corresponden a arbustos (selvas bajas, chaparrales y mezquitales) y 46.3 millones de hectáreas a matorrales (rosetófilo, micrófilo y crasicaule). Según datos del censo nacional de 1970, un 16% de la población total habitaba en estas zonas (cerca de 8 millones de personas), en condiciones de vida verdaderamente difíciles. En el informe 1972-1976 de CONAZA[3] se cita que en el área guayulera del estado de Zacatecas, el 3% de la población económicamente activa tenía ingresos menores de $ 200.00 mensuales, el 69% no rebasaba los $ 500.00, el 54% de las familias no consumían leche en todo el año y el 51% no incorporaban proteina animal dentro de su dieta. Algunas definiciones de zonas áridas y semiáridas, indican que en el caso de las primeras, la agricultura sólo es factible con riego, y para las segundas las cosechas de cereales son de muy bajo rendimiento, perdiéndose en cerca del 50% de los años o resultando totalmente antieconómicas.

En 1972 se estimaba que el sustento de 26 mil familias dependía de la extracción de la fibra de "palma samandoca" (*Yucca carnerosana*) (Marroquín 1964), por otra parte, las personas que se dedican a la producción de cera de "candelilla" (*Euphorbia antisiphylitica*), obtiene ingresos entre $ 500.00 y $ 1000.00 mensuales, en "lechuguilla" (*Agave lechuguilla*) $ 1000.00 mensuales, explotándose también otras plantas como la "jojoba" (*Simmodsia*

[1]Trabajo presentado en la Reunión de Inventarios y Recursos de Zonas Aridas. (La Paz, México, noviembre 30-diciembre 6, 1980).

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[3]Comisión Nacional de Zonas Aridas.

chinensis), orégano (Lippia palmeri), cactáceas y muchas más, que son un complemento importante o la fuente principal de ingresos, para la población de estas regiones, estimándose el valor de la producción de "candelilla" en el año de 1977 en 50 millones de pesos, y el de "lechuguilla" en 60 millones de pesos.

La legislación forestal de México señala que los aprovechamientos comerciales e industriales de matorrales o arbustos en general, deben efectuarse por medio de los planes de manejo correspondientes, aunque excluye los aprovechamientos de "ixtles de palma", "Lechuguilla" y "candelilla", situación que deberá corregirse en un futuro. Sin embargo, la realidad es que el aprovechamiento de las especies de las zonas áridas, se han realizado en términos generales atendiendo aspectos de carácter social, dejando en segundo término las normas técnicas que aseguren o incrementen la producción de bienes y servicios de estas áreas.

La información que se ha producido de los recursos de las zonas áridas en México ha sido escasa hasta la fecha y la definición de los diferentes niveles de necesidades de información para planeación, poco clara. A nivel nacional o regional, la Dirección de Estudios del Territorio Nacional y el Inventario Nacional Forestal, han producido información cualitativa consistente en cartas de tipos de vegetación y uso del suelo que comprende parcialmente las zonas áridas y semiáridas del país.

Figura 1.--Panorámica general de vegetación de zonas áridas en el norte de México (ejido Cosme, municipio de Ramos Arizpe, Coahuila).

Anteriormente se produjeron algunos estudios regionales con fines de planeación e investigación, como el "Estudio Dasonómico de las Zonas Aridas del Norte de México" realizado en 1961 por el INIF[4], el cual estuvo orientado a conocer áreas de distribución y densidad de acuerdo a diferentes habitats, de las especies más importantes. Otro estudio regional realizado en 1979, se enfocó a la detección de "palma china" (Yucca filifera) para programar cortes masivos del fruto.

En cuanto a manejo, se elaboraron dos estudios para "guayule" (Parthenium argentatum) (1972 y 1975), sin que hasta la fecha se hayan aplicado, debido a que en la actualidad no se aprovecha esta planta comercialmente. En 1978, el Inventario Nacional Forestal inició un proyecto de planes de manejo de especies de zonas áridas, realizándose los trabajos en plan piloto en un área de Coahuila, básicamente sobre "guayule", "lechuguilla" y "candelilla". Finalmente, a nivel de operación, el BANRURAL[5] realizó observaciones tendientes a programar la extracción de "candelilla", consiguiéndose información como: localización del recurso, cuantificación general, recursos humanos, distancias a vías de comunicación y centros de procesamiento, necesidades de equipo, etc.

TIPOS DE INVENTARIOS SEGUN NECESIDADES DE INFORMACION PARA PLANEACION

El correcto manejo de los recursos de las zonas áridas de México demanda información para planeación a diferentes niveles, los cuales pueden agruparse como sigue:

- Nivel nacional o regional
- Nivel de manejo
- Nivel de operaciones

En los niveles nacional o regional se requiere de información básica de apoyo, para el diseño de políticas, planes y programas, a mediano y largo plazo, referentes al aprovechamiento, protección, fomento, industrialización y comercialización, de los recursos de las zonas áridas. La ejecución y financiamiento de los inventarios para obtener la información de este tipo corresponde al gobierno federal, quien ha dispuesto que el Inventario Nacional Forestal inicie en 1980 los trabajos referentes al inventario nacional de zonas áridas, con el estudio en campo de alrededor de 1.5 millones de hectáreas en el estado de Coahuila.

[4]Instituto Nacional de Investigaciones Forestales.
[5]Banco Nacional de Crédito Rural.

Con fines de manejo de recursos es necesario contar con datos detallados para la formulación con fines de implementación, de planes y programas de uso, conservación y fomento de los recursos existentes, fundamentalmente a corto y mediano plazo, para ser aplicados en áreas específicas; como pueden ser los predios o los municipios. La información deberá indicar la cuantía, cómo, cuándo y dónde, deben efectuarse las recomendaciones del plan de manejo. Como se observa en el capítulo de antecedentes, la aplicación de estos planes en México ha sido prácticamente nula, lo que probablemente ha redundado en un deficiente manejo de los recursos de las zonas áridas. Uno de los principales obstáculos para la formulación de estos planes, independientemente de los problemas de carácter técnico, son sin duda los costos de los trabajos de inventario, los cuales difícilmente pueden ser financiados por los propietarios y en algunos casos las empresas industrializadoras. Una posible solución sería que fuera el gobierno quien elabore estos planes, aportando los fondos en los casos en que no fuera rentable el aprovechamiento y cobrando a las empresas las cantidades necesarias, cuando los productos tuvieran los márgenes de utilidades suficientes.

La planeación de operaciones requiere de información para elaborar programas de ejecución de actividades a plazos muy cortos (menos de un año), sobre trabajos de aprovechamiento, extracción, regeneración industrialización y comercialización. La ejecución de los inventarios de reconocimiento para recabar la información anterior, así como su financiamiento, debe recaer en las empresas privadas o estatales, que realicen la industrialización y comercialización de los productos de las especies de zonas áridas.

INFORMACION NECESARIA

Los diferentes tipos de inventarios deben proporcionar información para cubrir objetivos bien claros, pudiendo en ocasiones resultar de carácter complementario. De acuerdo a las condiciones de México, es posible en forma tentativa definir las necesidades siguientes:

INVENTARIO NACIONAL O REGIONAL

- Ubicación y localización del recurso en cartas a escala 1:50 000 o menores.
- Cuantificación de las superficies cubiertas por los diferentes tipos de vegetación, por clases de fisiografía, densidades y/o grado de perturbación.

Figura 2.--Medición del diámetro de una planta de "guayule" (Parthenium argentatum), durante los trabajos del estudio piloto de manejo de especies de zonas áridas, que está llevando a cabo el Inventario Nacional Forestal en el estado de Coahuila.

- Conocimiento del uso potencial del suelo, con información complementaria de climas, hidrografía, etc.
- Información sobre accesibilidad de los recursos.
- Frecuencias y existencias por grupo botánico y especies de interés.
- Posibilidades de aprovechamiento para especies comerciales.
- Tratamientos culturales y prioridades en los mismos.

La información anterior se destina a la formulación de políticas y planes a nivel nacional o regional, así como a la programación de trabajos y necesidades de financiamiento, para aprovechamiento, protección y fomento de los recursos.

INVENTARIOS PARA MANEJO DE RECURSOS

- Ubicación y localización del recurso en cartas escala 1:25 000 o mayores.
- Cuantificación de superficies de los rodales caracterizados por mezclas de grupos botánicos o asociaciones, cobertura y fisiografía.
- Clasificación por índices de productividad.
- Conocimiento del uso potencial del suelo e información complementaria de climas, hidrografía, etc.
- Frecuencias y existencias por grupos botánicos y/o especies por rodal.
- Tratamientos silvícolas y prioridades en los mismos.
- Información sobre turnos y ciclos de corta o recolección.
- Información de la división política y -

división predial.

La parte de la información anterior que se menciona también para el nivel nacional o regional, se requiere con un mayor nivel de precisión, pues se destina a la implantación de planes de manejo de recursos de las zonas áridas.

INVENTARIO PARA EJECUCION DE OPERACIONES

- Ubicación y localización de las áreas por trabajar.
- Características de los rodales seleccionados (distancias a caminos, pendientes, etc.).
- Necesidades de mano de obra.
- Requerimientos de equipo y materiales.
- Tiempos y costos de las actividades a desarrollar.
- Limitantes.

Estos datos permiten tanto ejecutar con mayor eficiencia las recomendaciones del plan de manejo, como auxiliar en la extracción de productos y cuantificar los requerimientos necesarios para las diferentes operaciones.

EFICIENCIA EN COSTOS Y RESTRICCIONES

Indudablemente que el tema que han marcado los organizadores de la reunión "Desarrollo de Métodos Eficientes en Costos", es de fundamental importancia en el inventario de los recursos de las zonas áridas de México. Se estima que el inventario nacional de los recursos de las zonas áridas del país llevará de 10 a 15 años. Indiscutiblemente que una reducción en los costos y tiempos de estos trabajos, deberá enfocarse principalmente a la investigación de técnicas de percepción remota, así como al uso de técnicas de muestreo más eficientes.

Los inventarios de manejo planteados en este trabajo se estiman difíciles de costear actualmente, por lo que las técnicas de medición en el terreno y los métodos de muestreo deben ser más eficaces, especialmente si se considera el aprovechamiento actual de algunas especies como la "candelilla", en el que los costos de producción son mayores a los precios de venta del producto.

Es posible definir que los inventarios de operaciones, deben realizarlos las empresas encargadas de la extracción e industrialización.

Entre las principales restricciones para llevar a cabo los inventarios de zonas áridas, se encuentran las siguientes:

- Carencia de investigación sobre: técnicas de fotogrametría y fotointerpretación, técnicas de medición y de muestreo; manejo de recursos de zonas áridas; silvicultura de zonas áridas y extracción de productos.
- Falta de financiamiento.
- Carencia de recursos humanos capacitados en las diferentes ramas necesarias.
- La escasa rentabilidad del aprovechamiento de algunos de sus recursos.
- El desconocimiento de las posibilidades de uso de una gran cantidad de sus especies.

CONCLUSIONES Y RECOMENDACIONES

- La planeación para el uso adecuado de los recursos de las zonas áridas requiere de inventarios a nivel nacional o regional, de manejo y de operaciones.
- Lo anterior es de una importancia prioritaria en México, donde el 38 % de la superficie del país, está cubierta por vegetación de zonas áridas o semiáridas.
- La información para la planeación de actividades en las zonas áridas de México, no es suficiente, ni va de acuerdo a las necesidades.
- El gobierno mexicano ha dado ya los pasos iniciales para corregir la situación mencionada anteriormente.
- Debe incrementarse la investigación sobre técnicas de inventarios y manejo de recursos de zonas áridas.
- Deben elaborarse los proyectos de inversiones necesarios, con el objeto de conseguir el financiamiento correspondiente.
- Debe realizarse un programa de capacitación de recursos humanos, sobre inventario y manejo de recursos de zonas áridas.

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SUMMARY

The adequate management of the arid land resources requires suitable infor-- mation for the correct planning of activities to be developed. This is very important in Mexico because about 38 % of the whole country (75.5 million hectares) is covered by arid land vegetation and a -- bout 16 % of the total population live in these regions.

Mexico's forest law indicates that - the commercial and industrial use of the arid land vegetation, needs a management plan, although is does not include the - utilization of "ixtles de palma" (*Yucca carnerosana*), lechuguilla (*Agave lechuguilla*) and candelilla (*Euphorbia antisiphylitica*). However, the fact is that the - utilization of the arid land resources, is carried out commonly on the basis of - social aspects, without employing tech--- niques to improve or preserve the arid - land production of goods and services.

There is almost any information related to arid land resources and the need of it at different levels is not clear. At national or regional levels, the Direc-- tion of the National Territory Studies -- and the National Forest Inventory have - produce qualitative information of arid land vegetation, concerning type of vegetation maps, that include partially the nation arid land.

There are some regional studies for planning and research, and two studies for "guayule" (*Parthenium argentatum*) management. In 1978 the National Forest Inventory started a project for management of arid land species.

The adequate management of the arid land resources requires information at - diferent levels: national or regional - management and operations.

Basic information is required at - national or regional levels for the - - outlinning of politics, plans and pro--- grammes at medium or long terms, for the correct use of these kind of resources.

The arid land resources management needs specific information for the implantation of plans and programmes at short - or medium terms. These data should indicate how, when and where the recomendations of the management plan should be fulfilled. The operations planning also requires - information to elaborate programmes of - activities, for short term plans (usually less than a year).

The different kinds of inventories - must give information, for specific ob-- jectives, and some times they may be - complemmentary.

Some limitations in carrying out the arid land resource inventories are: little research related to inventory tech-- niques in arid lands, lack of financing, few technicians, low profit in the utilization of some arid land resources and - ignorance of the different possibilities of use of the many arid land species.

It is feasible to conclude that the planning for the correct use of the arid land resources, requires national and -- regional inventories, management and -- operations, and all this is an important matter for the mexican economy.

Información Requerida para Evaluar Interacciones Entre Ganado y Fauna Silvestre.

J. M. Peña Neira[1]

Resumen.--Los animales domésticos y silvestres son recursos importantes de las zonas áridas. En este trabajo se presenta una compilación preliminar de las interacciones existentes entre ganado y fauna, y se sugiere un programa de investigación para evaluar estas interacciones, recomendando en casos específicos, las metodologías pertinentes.

CONVIVENCIA INEVITABLE

La ganadería ha sido la forma de explotación por excelencia de los recursos renovables en las zonas áridas, y el norte de México no es excepción a esta regla.

Con la introducción del ganado doméstico a Norteamérica, los ecosistemas se modificaron obligadamente. La fauna carnívora contaba ahora con una nueva presa, y los herbívoros nativos tenían en el ganado a un posible competidor. Viéndolo desde el punto de vista opuesto, el ganado es fauna introducida que convive inevitablemente con la fauna nativa. Esta convivencia puede resultar útil o nociva para los intereses ganaderos, dependiendo de las condiciones del medio. Conociendo los parámetros que norman las interacciones entre especies domésticas y silvestres se estará en posibilidades de disminuir los aspectos nocivos y optimizar los aspectos útiles de esta convivencia.

ANTECESORES

La introducción del ganado a Norteamérica fue efectuada sin ninguna base propiamente científica. Sin embargo, la adaptación de estos animales domésticos a su nuevo medio fue sorprendente. El caso del ganado no es único, sino que varias especies domésticas y silvestres han sido introducidas a Norteamérica con resultados satisfactorios, y en algunos casos, hasta amenazante contra especies nativas (Decker 1978).

El primer paso para comprender las relaciones ecológicas entre ganado y fauna, es el considerar las razones que condujeron a la supervivencia de las especies introducidas. Las teorías actuales atribuyen este éxito a la historia geológica de Norteamérica: a finales del Pleistoceno (10 000 A.C.) se extinguieron docenas de especies animales (principalmente mamíferos) en este continente. Estas extinciones provocaron la creación de nichos vacantes, espacios ecológicos que permanecerían vacíos hasta ser llenados a base de una nueva sucesión evolutiva del ecosistema, o bien hasta que una o varias especies introducidas los ocuparan, reemplazando a los animales extintos (Craighead y Dasmann 1974).

ANTECEDENTES EN MEXICO

Probablemente el único inventario ecológico de recursos ganaderos en las zonas áridas y semiáridas de México fue el llevado a cabo por CFAN-CID en 1965. Este levantamiento de datos se llevó a cabo mediante encuestas y evaluaciones en 600 predios ganaderos. Los cuestionarios incluían información sobre climatología, terreno, vegetación, prácticas de manejo de pastizales y agricultura, condición del ganado, manejo del mismo y aspectos de fauna silvestre (CFAN-CID 1965).

En este estudio se reportó que el 45% de los predios muestreados presentaban problemas de invasión de roedores y/o lagomorfos. También se estimó que el 9% de las muertes de ganado eran debidas a predatores, y se reportó que las especies de caza tendían a la desaparición en la mayoría de los ranchos. Se concluyó también que el problema número uno de los agostaderos del norte de México era el sobrepastoreo por ganado, factor que además de deteriorar la vegetación y erosionar el suelo, también afecta las poblaciones de fauna silvestre.

INVENTARIO INTEGRAL

Explicación del Diseño

El inventario ecológico aquí propuesto, fue diseñado desde el punto de vista ganadero, y en segundo lugar, desde el punto de vista de la fauna silvestre vertebrada. Además, en reconocimiento de que los animales domésticos y silvestres dependen

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directa o indirectamente de la vegetación, se ha tratado de incluír los estudios y evaluaciones pertinentes de este recurso. Por último, se recurre a los factores abióticos (clima, suelo, e infraestructura) como fuentes auxiliares.

Programa

Inventario Taxonómico

El primer paso en los programas de investigación y manejo de ecosistemas, es el conocimiento de los recursos existentes. La Taxonomía es un método filogenético para el inventario de los organismos. Otro de los objetivos del proceso taxonómico es la creación de una nomenclatura universal que permita la aplicación y retroalimentación de la información publicada.

Aunque en teoría el inventario taxonómico debe ser realizado con anterioridad a otros estudios, esto no siempre procede en la práctica. Por lo general, un centro de investigación se enfrenta a la demanda de información sobre aspectos específicos, de manera que los estudios básicos son relegados. Afortunadamente, la literatura disponible es bastante fuerte en cuestión de Taxonomía. Algunos proyectos de investigación o manejo podrán encontrar en una referencia bibliográfica toda la información taxonómica necesaria.

Especies Clave

Sería imposible estudiar todas las relaciones ecológicas existentes en una comunidad. De ahí que el investigador deba concentrar su atención en las especies que se encuentren en una relación más estrecha con las actividades ganaderas. La selección por estas especies clave resulta de la intuición y experiencia del investigador, revisiones de literatura y encuestas dirigidas a ganaderos y extensionistas.

La lista de especies clave no es inalterable. Por ejemplo, si al estudiar un predator del ganado se encuentra que éste muestra una gran preferencia por una especie de roedor, este último puede ser incorporado a la lista. De manera similar, si se sospecha de varias especies de fauna como causantes de un problema, y en los primeros estudios se descubre al veradero responsable, las demás especies pueden ser relegadas o eliminadas de la lista de especies clave, si el investigador lo considera prudente.

Encuestas

Intimamente ligadas con la selección de especies clave, están las encuestas dirigidas a extensionistas y ganaderos, concernientes a los problemas y experiencias que se tengan con la fauna silvestre.

Los cuestionarios para ganaderos deben estar elaborados en forma sencilla y breve. Entre los temas que pueden incluírse, están los siguientes: (1) Problemas con invasiones de pequeños mamíferos; (2) Problemas con predatores; (3) Prácticas de control que se lleven a cabo; (4) Utilización directa de algunas especies (alimento, cacería, pieles, etc.); (5) Situaciones en los ranchos vecinos; (6) Posibilidades de efectuar estudios en su propiedad.

Las encuestas deben ser complementadas con evaluaciones técnicas llevadas a cabo por el investigador o sus asistentes, tratando de formar un cuadro representativo de la situación en que se encuentra el predio (vegetación, topografía, clima, infraestructura, ganado, manejo, etc.).

El muestreo por medio de encuestas es muy delicado, y fácilmente se presta a obtener información errónea. Ejemplo: se envían cuestionarios a 200 ganaderos seleccionados al azar de una lista de miembros de la Union Ganadera. Mediante el cuestionario, se pretende obtener información sobre los problemas que tienen los ganaderos con predatores. Algunos de los posibles errores y desventajas de este muestreo son los siguientes: (1) Que solamente un porcentaje muy bajo de ganaderos contesten y devuelvan el cuestionario; (2) Que los miembros de la Unión Ganadera no constituyan una muestra representativa de la población predial; (3) Que serán principalmente los ganaderos severamente afectados por predatores quienes devuelvan el cuestionario aparentando que el porcentaje de ranchos con este problema es muy alto; (4) Que las pérdidas por predatores estimadas por los ganaderos se reporten sin el fundamento debido y de una manera exagerada; (5) Que se le dará la misma importancia tanto a propiedades grandes como a propiedades pequeñas.

Estos errores pueden ser minimizados efectuando las encuestas bajo las siguientes condiciones: (1) Muestreando sistemáticamente por medio de un mapa cuadriculado del área de estudio, donde todas las intersecciones correspondientes a predios ganaderos serán consideradas; (2) Estableciendo contacto personal con el ganadero; (3) Efectuando cuando menos una visita de inspección a cada rancho; (4) Efectuando un doble muestreo para corroborar o ajustar la información obtenida.

Mapeo de Areas Clave

La magnitud y potencial de una interacción entre fauna y ganado puede evaluarse de diferentes maneras. Una de ellas es determinar su extensión geográfica. Un mapeo de estas interacciones puede dar la base para entender una situación y establecer un orden de prioridades en la investigación.

En el caso de áreas problema, como la invasión de varias especies de roedores, la especie que abarque un área mayor puede tomarse como la prioritaria. En el caso de especies deseables, como el venado cola blanca (*Odocoileus virginianus*) y el berrendo (*Antilocapra americana*), el investigador pudiera estar mayormente interesado en la especie que se encuentre más recluída, con el propósito de protegerla y evitar su extinción.

Estudios Biológicos

Resultaría incompleto evaluar las relaciones entre dos o más poblaciones sin conocer el

funcionamiento individual de cada una de ellas. En algunos casos, la información biológica fundamenta o explica las relaciones ecológicas; en otros, proporciona conocimientos que permiten optimizar su manejo. Estos estudios biológicos pueden versar sobre fisiología, comportamiento, patología, dinámica de poblaciones, y autoecología.

Ejemplo: Los vampiros (Desmodus rotundus) causan problemas a la ganadería debido a la transmisión del derriengue e infestación de las heridas por moscas causantes de la miasis. En estudios sobre comportamiento de vampiros, se ha observado que éstos forman colonias donde friccionan unos con otros. También se ha observado que estos quirópteros generalmente regresan a reabrir las mismas heridas. Estos patrones de comportamiento sirvieron de base para desarrollar métodos de control, aplicando substancias anticoagulantes en el dorso y vientre de vampiros capturados, que al ser puestos en libertad, transmitían el tóxico a sus congéneres por simple contacto. También en base a su comportamiento, se desarrolló la técnica de aplicar el anticoagulante en las heridas causadas al ganado (Flores Crespo et al. 1976).

Daños y Beneficios

Como una parte anexa del programa, está el estudio y evaluación de los daños y beneficios resultantes de las interacciones entre ganado y fauna silvestre.

Muchas veces se tendrá que empezar por detectar el problema en sí, o bien descubrir los aspectos útiles. Generalmente resulta más sencillo, tanto para el investigador como para el ganadero, percatarse de un daño que descubrir un beneficio, ya que por lo regular los daños son visibles, no así los beneficios.

Pronóstico de Interacciones

Aunque los daños sean perceptibles, no siempre son predecibles. Esto se debe a la falta de información sobre la naturaleza de estos daños. Precisamente uno de los objetivos principales de un inventario (e.g. inventario climatológico) es pronosticar situaciones.

En algunos casos, la literatura provée suficiente información para poder predecir una situación. Ejemplo: una resiembra de agostadero en una zona invadida por perrito de la pradera (Cynomys spp.) tiene mínimas probabilidades de éxito (Medina 1976).

La mejor manera de controlar un daño es prevenirlo. Cuando esto no es factible, y el problema ya se ha manifestado, los siguientes factores deben considerarse antes de efectuar un control (Anderson 1971): (1) Evaluar el daño ocurrido; (2) Estimar el daño por ocurrir; (3) Analizar el costo/beneficio del control; (4) Inferir las probabilidades de éxito de la operación; (5) Considerar el valor estético de la especie problema; (6) Predecir el impacto del programa de control sobre otras especies ajenas al problema.

Pequeños Mamíferos

Impacto Sobre la Vegetación.--La fauna silvestre, en particular los roedores y lagomorfos, con frecuencia es culpada de la deteorización del agostadero. Este juicio demanda estudios que evalúen el efecto de la fauna sobre la condición del pastizal y la sucesión vegetal. El empleo de exclusiones es probablemente el método más efectivo para efectuar estas determinaciones.

Competencia con el Ganado.--El argumento más fuerte de los ganaderos en contra de las liebres, conejos, y roedores, es el de que estos animales consumen forraje que podría aprovechar el ganado doméstico (Peña Neira 1980).

La competencia potencial por forraje entre fauna y ganado es difícil de estimar. Además, estas determinaciones se complican debido a la falta de información adecuada, particularmente en México (CFAN-CID 1965). Para poder evaluar esta competencia se deben considerar los siguientes estudios (Stoddart y Smith 1955): (1) Determinar la densidad de poblaciones silvestres y sus requerimientos cuantitativos de forraje; (2) Calcular la disponibilidad de alimento; (3) Estimar la similaridad de la dieta del ganado con las dietas de especies silvestres; y (4) Determinar hasta qué grado el ganado y la fauna utilizan las mismas áreas.

Transmisión de Enfermedades.--Los animales silvestres son portadores de parásitos. Algunos de estos gérmenes pueden eventualmente ser transmitidos al ganado, Esta fuente de investigación no ha recibido mayor atención en el norte de México, probablemente debido a que generalmente los problemas de enfermedades del ganado no son tan graves en las zonas áridas como lo son en el trópico.

Argumentos y Contraargumentos.--Las opiniones acerca de los pequeños mamíferos son divergentes. Fogden (1978) presentó 5 argumentos en contra de roedores y lagomorfos, con sus respectivos contraargumentos que defienden los aspectos útiles de estos animales. Solamente a través de estudios adecuados se podrá establecer la posición ecológica de estas especies, y las influencias que el medio pueda ejercer sobre sus actividades.

Argumentos en contra	Argumentos a favor
Consumo y destrucción de forraje	Consumo y destrucción de plantas indeseables
Consumo y destrucción de semillas deseables	Consumo y destrucción de semillas indeseables
Dispersión de semillas indeseables	Dispersión de semillas deseables
Erosión del suelo a causa de madrigueras	Descompactación y aireación del suelo
Animales indeseables en el agostadero	Valor cinegético y alimenticio

Predatores

Sujetos de Controversia.--La falta de una información integral e insesgada ha hecho de los predatores típicos sujetos de controversia. Este es otro caso en que los argumentos a favor y en contra deben ser comprobados o refutados experimentalmente. Ejemplo: Se dice que cuando los predatores atacan al ganado, eliminan animales con deficiencias genéticas, o bien individuos enfermos ya condenados a morir. Estudios recientes han refutado ya varias veces esta hipótesis, encontrándose que hay inclusive ocasiones en que son los animales más saludables los sacrificados por predatores (Connolly 1978).

Confirmación e Identificación del Daño.--Las pérdidas de ganado debidas a predatores rara vez son reportadas con precisión por el ganadero. Con frecuencia los predatores consumen carroña, dejando sus huellas alrededor del cadáver, sin haber participado en la muerte del animal. De manera similar, los estudios sobre la dieta de predatores no revelan si el material ingerido proviene de un ejemplar cazado por el predator, o de un animal que ya se encontraba muerto.

En un estudio donde se pretenda evaluar cuantitativamente las pérdidas debidas a predatores, se debe contar con un técnico dedicado constantemente a la inspección de los animales recientemente muertos en el área de estudio. En base a la presencia de signos de contienda, arrastre, derrapes, marcas de dientes o pezuñas, posición del cadáver, formación de coágulos, partes preferidas, huellaje, etc., el técnico podrá descartar o confirmar la predación, e inclusive identificar al predator (Anderson 1971).

Especies de Caza

Explotación Irracional.--La fauna cinegética es uno de los recursos renovables más valiosos en los agostaderos. En México, sin embargo, sus poblaciones se encuentran muy por debajo de su potencial, y recluídas a lugares donde el disturbio es mínimo. Esta situación se atribuye a dos factores: (1) Cacería inmoderada; y (2) Pérdida de habitat.

Ranchos Cinegéticos.--Aunque el ganadero se siente orgulloso cuando en su rancho son comunes los ejemplares de caza, sólo raras veces comprende y aprovecha todas las ventajas que este hecho le brinda. Por una parte, es posible obtener beneficios económicos por medio del alquiler del rancho a cazadores, o bien disfrutar de este deporte en forma privada. Otra manera de aprovechar las especies cinegéticas, es la de balancear la utilización de la vegetación mediante el pastoreo combinado de especies domésticas y silvestres (Fogden *et al.* 1978).

Centros de Repoblación.--Dada la situación crítica en que se encuentra la fauna en los agostaderos del norte de México, se puede afirmar que uno de los estudios más urgentes a este respecto es la búsqueda de predios ganaderos con potencial para albergar poblaciones silvestres, no solamente aquéllas con valor cinegético, sino cualquier especie con valor económico, ecológico, o estético. Es decir, levantar un inventario de localidades que sirvan como centros de repoblación de especies deseables, que a su vez podrían operar como ranchos cinegéticos. En este inventario sería aconsejable incluír lo siguiente: (1) Localización y extensión del predio; (2) Tipo de propiedad; (3) Infraestructura; (4) Manejo del agostadero y el ganado; (5) Análisis de vegetación y topografía, desde el punto de vista de las necesidades de la fauna; (6) En base al punto anterior, determinar cuáles especies tendrían mayores posibilidades de desarrollarse satisfactoriamente en ese lugar; (7) Identificar las especies clave que ya se encuentran presentes en el área, o que alguna vez se encontraron; (8) Estimar el grado en que se efectúa cacería ilegal en el área, y las posibilidades de controlarla; (9) Conocer la disposición de los propietarios y residentes para que dicho programa de repoblación se lleve a cabo.

Especies Introducidas.--Se ha discutido mucho sobre la introducción de especies exóticas a Norteamérica, teniéndose opiniones a favor y en contra (Decker 1978). Algunos exóticos, sin embargo ya se han introducido accidental o intencionalmente, y el conocimiento de estas especies es necesario. También se ha hablado de la introducción de especies para su utilización como "ganado silvestre" aprovechando la existencia de los ya mencionados nichos vacantes. Toda introducción futura deberá efectuarse bajo previa investigación científica, recluída a exclusiones experimentales. Especies como la saiga (*Saiga tatarica*), el addax (*Addax nasomaculatus*), el gerenuk africano (*Litocranius walleri*), y otros, ofrecen potenciales para su adaptación y aprovechamiento en los agostaderos del norte de México y Sur de los Estados Unidos.

Beneficios Discretos

La fauna proporciona beneficios a la ganadería, difíciles de evaluar económicamente. Así, los predatores ejercen un control sobre las poblaciones de roedores y lagomorfos; algunos herbívoros consumen plantas invasoras; las aves carroñeras ayudan al ganadero en la localización de animales muertos, y aceleran su descomposición.

La fauna es también una valiosa y experimentada fuente de información para el manejo de pastizales y ganadería. Los sistemas de rotación de potreros han sido llevados a cabo por el bisonte (*Bison bison*) desde hace millones de años. El caribú (*Rangifer tarandus*) es un modelo natural que nos enseña las ventajas del establecimiento de una época de empadre, la cual practica en un término de 1 a 2 semanas, pudiendo de esta manera enfrentarse a las fluctuaciones climáticas estacionales e incrementar las probabilidades de supervivencia ante la presencia de predatores (Bergerud 1978).

Casos como estos permanecen aún ocultos. Los ecólogos tienen todavía mucho por aprender acerca de la fauna de zonas áridas, y aprovechar la experiencia evolutiva de las especies silvestres para aplicarla en el manejo de pastizales y ganadería.

Efecto del Ganado sobre la Fauna

Las actividades ganaderas, a su vez, influyen sobre las poblaciones de fauna silvestre. El pastoreo por especies domésticas puede tener efectos considerables sobre la calidad del habitat de la fauna. Estos aspectos dependen de los siguientes factores (Wolfe 1978): (1) La especie de ganado; (2) La especie de fauna; (3) La carga animal; (4) El sistema de pastoreo; y (5) El tipo de vegetación. En base a estos factores, el ganado es capaz de perjudicar algunas especies y beneficiar a otras.

La infraestructura ganadera es también importante para la fauna (Yoakum y Dasmann 1971). De aquí la necesidad de diseñar cercos ganaderos congruentes con los movimientos migratorios de los ungulados silvestres. Las postas de los cercos también sirven como puntos de acecho a las aves de rapiña. Los aguajes construídos para el ganado también son aprovechados por la fauna. Todo este tipo de información es importante para poder establecer programas de manejo de ranchos donde se considere también a los animales silvestres.

Si bien la ganadería ha afectado negativamente a la fauna, también lo ha hecho en forma benigna. Además, es lógico suponer que si no existiera la ganadería, la presión de cacería sobre las especies nativas sería mucho más intensa.

CONCLUSION

Las interacciones ecológicas entre ganado y fauna silvestre son diversas y complejas, de manera que requieren de un estudio detallado. La experiencia empírica de la gente de campo es una fuente de información muy útil, que merece ser evaluada científicamente.

El primer y último inventario ecológico de recursos ganaderos en las zonas áridas y semiáridas de México se efectuó en 1965. De entonces a la fecha, la literatura concerniente a la ecología de agostaderos se ha incrementado lo suficiente para permitir la planeación de un nuevo inventario con información actualizada y de mayor alcance. Uno de los aspectos a reforzar es la situación de las interrelaciones ganado-fauna. El autor espera que esta presentación pueda servir de ayuda para éste y otros propósitos, referentes al conocimiento y explotación de recursos en zonas desérticas y semidesérticas.

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INFORMATION REQUIREMENTS FOR EVALUATING WILDLIFE-LIVESTOCK INTERACTIONS

Domestic and native animals are renewable resources of primary importance in arid lands. Good range management optimizes the combined exploitation of livestock and wildlife, and minimizes conflicts between them. Livestock-wildlife interactions can be understood through well-planned investigation. Suggested research guidelines are presented as follows: (1) Taxonomic inventory (universal procedure; permits feedback); (2) Selection of those wildlife species closely related to ranching activities (based on researcher's experience, literature reviews, and survey of ranchers); (3) Survey of ranchers' concerns about wildlife (problems, control practices, management and exploitation); (4) Localization and quantification of key areas (as a guide to understand the interactions and set research priorities); (5) Biological characteristics of featured species (physiology, behavior, pathology, population dynamycs, and autoecology); and (6) Evaluation of wildlife damages and benefits to ranchers, their land, and animals (impact on vegetation, disease transmission, competition, compatibility, and wildlife values). Gathered information can be used towards the development of three major management disciplines: (1) Management of livestock and their potential competitors (with emphasis on small mammals); (2) Management of livestock and their predators; and (3) Management of livestock and game species.

The Analytical Basis for Integrated Forest and Rangeland Ecosystem Inventory[1]

JOHN H. WIKSTROM[2]
and
THOMAS W. HOEKSTRA[3]

Abstract.--There is a growing awareness of the need to deal with nature as a synergistic system, and natural resources as products of the system. Progress in developing a systems-oriented inventory has been painfully slow for a number of reasons including a limited level of understanding of nature as a synergistic system, problems of preconditioning, and lack of tools and techniques, especially lack of an adequate ecological land classification system. The analysis to be made determines the nature of the classification required and the data to be provided through inventory. The question(s) to be answered and the context in which it (they) must be answered determine the analysis. This paper summarizes our experience and understanding of forest and rangeland inventory from the standpoint of questions, context, and analysis in the United States.

Growing pressures on all ecosystems--desert, arctic, temperate, and tropic--have greatly increased awareness of our dependency on nature.[4] We are becoming increasingly aware that maintaining the stability of the environment means using products of nature consistent with (1) the productive capacity of nature, and (2) man's capacity to increase productivity. We are forced, in terms of forest and rangeland inventory, to step back from our traditional approach of inventorying the products of natural system, such as trees, forage, wildlife, etc., and address these lands more fundamentally. We must develop forest and rangeland classifications and inventories that better reflect ecosystem capability to produce the products of interest and respond to management.

[1]Paper presented at the international workshop, Arid Land Resource Inventories: Developing Cost Efficient Methods, Nov. 30-Dec. 6, 1980, La Paz, Mexico.

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[4]The sum total of all things in time and space.

Progress in developing such an integrated systems approach to forest and rangeland classification and inventory has been painfully slow because it is a complex and difficult problem. It is a complex problem because it involves more than the land and the products it produces; it also involves people, how we perceive the land and what it produces, and the factors that affect how we perceive the land and associated resources.

While measurement techniques are inadequate in many respects, a far more serious problem is our perception of nature itself, and the nature and purpose of inventory.

Land systems inventory calls for more than an integration of functional inventories. It calls for an integration of the functional components of knowledge independently developed by the various science disciplines, even though nature was not always perceived as an integrated whole. Many pieces of knowledge developed are not in a form that makes them directly integratable, or the concepts to integrate them have yet to be developed.

By early in this century it was well established that nature is a dynamic system involving movement and change, even randomness. The awareness that nature is a synergistic system--that is, a system that can not be explained or predicted by the separately observed behavior of its

parts and sub-systems--did not come until well into this century. This idea of nature as interrelated and interdependent systems and processes led to the awareness that no fact about nature could be fully understood except in relation to some concept of the whole, a concept that linked the social-political and biophysical processes.

Most North American colleges and universities with programs in agriculture and forestry offer training in forest and rangeland inventory. However, training within the context of nature as systems has been overlooked for more in-depth training in measurement methods. Most undergraduate programs require a background in inventory tools: mathematics, statistical methods, and measurement techniques. In addition, they usually start with the premise that systems can be dealt with in terms of components or parts. Further, they assert that to develop a management plan, the first step is to make an inventory. Implied in the premise is some concept of nature and kind of analysis which usually is left unspecified. As a consequence many natural resource specialists are left with an unclear picture of how the content of an inventory is determined or used. They are, in effect, preconditioned to believe that an inventory inherently provides certain information, and they proceed to plan and conduct inventories on that basis.

The purpose of this paper is to better explain the inventory specified by integrated analysis, and to relate analysis to inventory planning.

Some Basic Observations

The obvious but generally overlooked first step in planning an inventory of forest and rangeland is to plan the analysis. It is the nature of the analysis to be made that determines the nature of the classification system(s), criterion required, and the data to be acquired. The first question therefore, is: what determines the nature of the analysis?

Two things determine the nature of the analysis. One is the issue, or concern to be addressed; the other is the natural context in which the question(s) must be answered. The overall question the U.S. Forest Service is concerned with is the allocation of forest and rangeland, associated resources, and management efforts to best meet the needs of the Nation. The analysis context is integration of ecological, economic, and social concepts of nature.

In the United States, legislation commonly referred to as RPA[5] specifies that the question be addressed in an integrated manner. This legislation does not substantively change the <u>kind</u> of information that has been collected, but it does change <u>how</u>, <u>when</u>, and <u>where</u> the information is collected and analyzed. The legislation requires analysis consistent with current understanding of nature as a collection of open, synergistic systems.

Basic to planning the analysis is an understanding of the significance of this change in the concept of nature. To illustrate, land in the ecological sense is more than terrestial earth or aquatic surface. Land exists as basic interrelated ecological systems that have the productive capacity to supply such things as timber, forage, animals, etc.

Also, while the analysis involves applying joint production concepts of economics to ecosystems, the factors of production are not simply land, labor, and capital as economic science has traditionally held. When man is considered as a part of nature, resources and labor are not capital free (that is, without value to society) as is commonly assumed in economic analysis. The factors of production then are interactive land systems; energy, including human energy; knowledge; and capital.

Knowledge which costs society to develop, is an important factor of production. The well-being of society thus depends on achieving knowledge which produces increasingly greater harmony with the environment.

Implied in the preceding is a somewhat different model than the land, labor, capital models with which inventory specialists are familiar. It implies a model in which man is an integral part of nature.

Before effective forest and rangeland inventories can be developed, it is necessary to get a better understanding of the analysis, including context, that is required.

The Conceptual Model

The Renewable Resources Planning Act recognizes nature as interacting ecological systems that are interdependent and capable of producing a number of outputs. These systems will produce some output without management, and more with management. In other words, the total output vector ($\underset{\sim}{O}$) from an ecosystem at any point in time (t) is a function of the ecosystem and management.

$$\underset{\sim}{O} = f(\text{ecosystem, management})_t$$

Further change (Δ) in the output could result from a change in the ecosystem or a change in management, or a change in both:

$$\Delta\underset{\sim}{O} = f(\Delta\text{ecosystem, }\Delta\text{management})_t$$

[5] Forest and Rangeland Renewable Resources Planning Act (1974) as amended by National Forest Management Act (1976) and complemented by the Cooperative Forestry Assistance Act (1978) and the Forest and Rangeland Renewable Resources Research Act (1978).

If we had the capability to fully understand how social, economic, and ecological processes interact, we might be able to fully analyze the consequences of change with the above model. The fact, however, is that we lack that ability. United States legislative direction recognizes this, and specifies an analytical process that encompasses three separate but sequentially related analyses (Alston, 1979). These analyses are:

1. An ecological analysis addressing the question; Is the environment capable of withstanding the change?
2. An economic efficiency analysis addressing the question: is it worth it; and
3. Public review addressing the question of equity and political acceptability: Does society want it?

An Integrated Analysis Model (IAM) is composed of a series of separate models from which the final outputs ($\underset{\sim}{O}$) are a function of sequential ecological (EA), economic efficiency (EE), and public review (PR) analyses.

Having established an analytical process reflecting the context of nature, the next step in planning the analysis is to identify the ecosystem product outputs. In the case of the U.S. Forest Service, legislative direction and Department of Agriculture regulations (Federal Register 44:181) specify eight categories of outputs:

O_T = timber
O_F = forage
O_R = recreation
O_{WF} = wildlife/fish
O_W = water
O_{WL} = wilderness
O_M = minerals
O_H = human resources.

And, where:

$\underset{\sim}{O}$ = vector of all outputs, T...H.

The U.S. Forest Service is to maximize the combined net benefits to society derived from the management of current and future forest and rangeland base. Funding to produce these benefits requires prioritization in terms of the part of each ecosystem to which to apply management of different types and intensities. In addition, the legislation imposes other constraints: there must be no deterioration of basic land capability, and no irreversible damage to the environment.

The matter of requirements on the analysis are of basic concern. Nature produces some of each ecosystem product without management. It is important to determine the output level of nature, which we call environmental services (O_{ES}) because it forms the basis for measuring change in the capability of the ecosystem. Also, we should not give credit to management in any analysis for what nature produces alone.

The first question is, what determines the level (quantity) of output of each of the products listed? In a functional mode it could be said that the level of output of a particular ecosystem product, say timber, is equal to the timber that nature alone would provide as annual surplus of the ecosystem (O_{ES}) without management, combined with the annual production resulting from the management applied (figure 1). In this figure, P_i represents the number of acres allocated to the ith management prescription; R_{ji} represents the jth output response to the ith prescription.

In an integrated mode, determining the level of output is more complicated. To continue with the timber example, the level of timber output (O_T) is a function of the natural capacity of a particular ecosystem to produce timber, plus that resulting from management practices. It can be expressed as follows for any resource of an ecosystem:

$$O_T = O_{ES,T} + \sum_{i=1}^{n} R_{Ti}$$

FIGURE 1

MATRIX for
1990 RESOURCE ASSESSMENT INFORMATION SITUATION

Ecosystem: ______________
Decision Level: Forest ' State' region ' Nation

Ecosystem Products		O_{ES}	Response to Mgt. Prescription P_1		P_n
O_T =	(a)	$O_{ES,T}$	R_{T1}	...	R_{Tn}
O_F =		$O_{ES,F}$	R_{F1}	...	
O_W =		$O_{ES,W}$	.		
O_{WF} =		$O_{ES,WF}$	.		
O_R =		$O_{ES,R}$	.		
O_M =		$O_{ES,M}$	.		
O_{WL} =		$O_{ES,WL}$	.		
O_H		$O_{ES,H}$	R_{H1}	...	R_{Hn}

The simultaneous solution of the above equations for all ecosystem products represents the integrated solution in physical output terms for all ecosystem products. Each line or row represents the partial solution for the particular ecosystem product output.

The ecological analysis (EA) is concerned with the potential change (Δ) in the ecosystem resulting from the management programs applied, and related to each output at a particular point in time (t).

The equation can be written as follows:

$$\Delta \underset{\sim}{O} = (\Delta O_T, \Delta O_F, \Delta O_W, \Delta O_{WF}, \Delta O_R, \Delta O_M, \Delta O_{WL}, \Delta O_H)$$

where:

$\Delta \underset{\sim}{O}$ = the change in the ecosystem output vector in time t.

$$\Delta \underset{\sim}{O}_T = \Delta \underset{\sim}{O}_{ES} + \sum_{i=1}^{n} \Delta R_{Ti}$$

Given an understanding of the relationship of multiple ecosystem product outputs to natural effects and management effects, it is then possible to consider the combination of outputs possible from a single land management practice or prescription (any combination of management practices).

The above deals only with physical outputs from an ecosystem. For purposes of economic efficiency analysis, the cost of management practices or prescriptions must be distributed across all outputs and evaluated against the value of the outputs. The equation for determining the most economically efficient allocation (EE) for an ecosystem can be written as follows:

$$\text{Maximize: } NV = V_{TOT} + V_{FOF} + \ldots V_{HOH} - \left(\sum_{i=1}^{n} C_i P_i\right)$$

where:

NV = the net value of all products

Vj = the value of the jth output j = t, F, . . ., H.

Ci = the cost of the ith management prescription per acre applied.

Pi = the number of acres on which the ith prescription is applied.

An important purpose of public review is to provide analysts with a basis for weighing the results of the economic efficiency and environmental change analyses. It cannot be assumed that exchange values or prices equal output values, or that shadow prices or other assigned price coefficients adequately reflect societal values (equity). Public review of the results of the economic efficiency analysis and environmental analysis hopefully provides input useful in making adjustments in the final allocation.

The equation for the final analysis (PR) can be written as follows:

$$PR = w(NV_K, \underset{\sim}{O}_K, \Delta \underset{\sim}{O}_K, \Delta \underset{\sim}{O}_{ES_K})$$

where w is a preference function indicating ordering of K alternative output vectors.

Because there is no methodology for dealing with ecological analysis, economic efficiency, and public review simultaneously, the integrated analysis model (IAM) comes down to the sequential integration of three separate analyses (EA + EE + PR) for a particular point in time (t), as was indicated earlier.

Inventory and the Model

The preceding is the conceptual analytical model, assuming an ecological basis of integration, toward which we are moving in the United States. Bear in mind it is a conceptual rather than an operational model. The specific data requirements for implementing the concept will be defined following completion of a comparison between the existing analytical methods and the conceptual mode. Deficiencies in analytical methods will define needed research. Capabilities of existing analyses will provide guidance on data needs.

Two attempts by the Forest Service to develop a national level operational version (USDA 1972; Ashton 1980) have been partially successful. Two critical deficiencies were the lack of a suitable hierarchial and spatial ecological land classification system (Bailey et al., 1978) and data describing how different components of the ecosystem interact and how land management practices interact with each other and affect the natural capacity and output of the ecosystem. Available ecological classifications used were essentially single level rather than multilevel and hierarchial, and management interaction coefficients had to be developed using the Delphi method.

From the standpoint of forest and rangelands inventory, it is critical that data are collected on an ecological basis, and that they can be aggregated to different levels of spatial ecological resolutions for analysis. In terms of the specific data collection sample points, it is essential that multiresource information needed for quantifying the interaction of different components be obtained from the same sample point, and that sample points be distributed to provide a spatial systematic sample of the ecosystem. Also, it is critical that the inventory be designed to provide measurements of change and relationships in the ecosystem so that, over time, interaction coefficients can be developed objectively through analysis of the data.

A nine-level ecosystem hierarchy outlined for the United States, and the nation has been mapped to the fifth level (Bailey 1976, 1978). This spatial hierarchy has yet to be tested in analysis. Preliminary test data suggest that it has promise for forest and rangeland trade-off analyses. Research now underway at the Rocky Mountain Forest and Range Experiment Station is designed to strengthen land classification, and to provide guidance for melding the state-of-the-arts in classification and inventory, considering also the need to develop interaction coefficients.[6] Our objective is to produce information needed for joint production analysis with either qualitative or quantitative interaction coefficients in 1989 that are directly useful in program development.

We are not proposing a totally new or largely renovated analysis and inventory system to replace current practices. We are suggesting an analysis that focuses on the ecosystem, and that puts ecological, economic, and social equity aspects in better perspective. This will affect inventory, requiring changes in three areas: 1) measurement of unique ecosystem product attributes, 2) at a minimum, the sampling base will have to be stratified to the lowest level of the spatially contiguous ecosystem needed for National-level decisionmaking and, 3) new data needed for ecosystem products not previously measured in functional inventories.

The major change will occur in the organization or context of how the inventory data will be used in the analyses. In addition to the analysis of the current situation, the development of trends is equally as important. Any suggested change in analysis or inventory must provide the needed continuity with past inventories for trend analysis.

We have presented in brief an analytical basis for ecosystems inventory. Our basic argument is that it is the nature of the analysis to be made that determines the nature of the classification systems and inventory required. We argue that the joint production analysis is the context within which inventory must be addressed. It is particularly important to distinguish change in context from change in content. For those who would like more in-depth information on the basic concept, we suggest Kenneth Boulding's (1978) basic work on ecodynamics. The model we have presented is described in more detail in a Rocky Mountain Forest and Range Experiment Station report available from the authors.[7]

[6]Driscoll, R. S., J. Russell, and M. Meyer. 1978. Recommended National land classification system for renewable resource assessment. USDA Forest Service. Task Group Report. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Colorado.

[7]Hoekstra, T. W., J. H. Wikstrom, Max Keetch, and Doyle Turman. National information needs and use in the 1990 assessment. Report #1. USDA Forest Service. Staff Paper. Rocky Mountain Forest and Range Experiment Station. 240 West Prospect Street, Fort Collins, Colorado. (Review Draft).

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RESUMEN

Se está tomando conciencia de la necesidad de mediar con la naturaleza como un sistema sinergético, y con los recursos naturales como productos de ese sistema. El desarrollo de un inventario orientado hacia sistemas ha sido muy lento debido a varias razones, entre ellas un nivel limitado de considerar a la naturaleza como un sistema sinergético, problemas de precondicionamiento, y falta de instrumentos y técnicas, especialmente falta de un sistema ecológico para la clasificación de tierras. El análisis que se ha de hacer determina la naturaleza de la clasificación requerida, y la data que se debe proveer a través de un inventario. La (s) pregunta (s) que ha(n) de contestarse y el contexto en que se debe(n) contestar determina(n) el análisis. Este trabajo resume nuestra experiencia y conocimiento sobre inventarios de bosques y pastaderos desde el punto de vista de preguntas, contexto y análisis en los Estados Unidos.

Climatic Data Needs for Efficient Management of Arid Lands[1]

Martin M. Fogel and Manuel Anaya G.[2]

Abstract: Efficient management of lands involves a trade-off between productivity and environmental protection. Event-based precipitation models are suggested as a better approach than using equal-time interval data for making evaluations. These models are recommended where data are scarce, where conditions are changing and optimal decisions are desired.

INTRODUCTION

Efficient management of lands, be they arid or otherwise, may be considered to be evaluation of a trade-off between productivity and conservation of natural resources. For this paper, arid land productivity refers to their capability for sustained production of food and fiber while conservation of natural resources considers both the availability of land and water and environmental enhancement.

Man's pastoral and agricultural activities in the more arid regions of the world have often been accused of being responsible for the spread of desert-like conditions. It can be argued, however, that such statements are made without consideration of other causative factors for these conditions, namely, the climatic influences. Information is needed by managers that will allow them to employ techniques and practices that will sustain production consistent with limiting environmental degradation. Recognizing that arid lands exhibit great climatic variability, this paper focuses on the variability of precipitation in time and space and on management models that utilize climatic inputs to generate desired outputs such as water and vegetative production.

CLIMATE OF ARID LANDS

Numerous attempts have been made to delineate the margins of the arid zone by climatic data such as rainfall, temperature and evaporation (Walton, 1969). This section does not add to the methodologies for classifying lands as being arid but rather discusses climatic fluctuations and climatic prediction and significance of arid land precipitation.

Climatic Fluctuations

Climatic variability increases with aridity and, in an agricultural sense, becomes more important as food reserves approximate the amount of annual production variation due to the natural fluctuation of weather (National Research Council, 1976).

Economists and others have tended to regard climate in non-varying terms to be included in an economic model as a constant. This is partly because climate has, traditionally, been narrowly defined as "the average weather." Maps of average temperature, average precipitation, average number of days with clouds or sunshine, and similar averages, are included in geography textbooks and books about climate. Meteorologists have also contributed to this interpretation by uncritical use of the terms normal and departure from normal. Moreover, the sheer bulk of accumulated data combined with lack of adequate data processing has meant that only the simpler statistical concepts have been explored.

A more sophisticated analysis suggests that the concept "climate" should be defined in terms of the complete statistical properties of atmospheric events over various periods of time and over various regions, including not only the averages but the variability and the extremes as well (National Research Council, 1975).

Predicting Climate

Information on weather is crucial to agricultural planning on both global and local levels. To some extent, farmers can control their production but they are ultimately powerless against

[1]Paper presented at workshop on Arid Land Resource Inventories: Developing Cost-Efficient Methods. La Paz, Mexico, November 30-December 6, 1980.

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catastrophic events or consistently unfavorable weather. In addition, prices are increasingly being determined by global, not local, considerations.

Potential crop yields can be predicted from models of various combinations of climatic variables. The combinations used depend upon the crop and the geographical area. In order to provide information necessary for crop production on a long-term as well as a short-term basis, the periods selected for examination should be sufficiently short, and the areas sufficiently small, to make prediction of crop production feasible and to minimize the effect of averaging. In some drier regions, wheat yields have been estimated using figures for precipitation accumulated over an extended period of months, but averages for shorter time periods are generally used. Other systems use weekly and daily values of weather parameters. To be timely and useful to agriculture, climatic fluctuations for assessing yields must be considered for seasonal periods.

Many economic benefits of significantly improved seasonal weather forecasts would accrue to the agricultural sector were they available. One of the problems to overcome is the tendency for climatic "noise" (or randomness) to obscure significant nonrandom change in climate models. Recent studies have indicated that long-range forecasting based on model calculations may not be much more effective than the use of linear regression based on the statistical properties of observed anamolies (National Research Council, 1976). In either case, there are important limitations imposed by sampling errors associated with climatological records of finite duration. While an understanding of the behavior of the climatic system is not yet on hand, knowledge of the system on which climate impacts is also not complete.

Significance of Arid Land Precipitation

Rangeland is the largest single category of land, comprising about 40 percent of the earth's land area. Of this 40 percent, roughly 80 percent is within arid and semiarid zones (National Research Council, 1976). It produces a variety of natural resources beneficial to man, but forage for livestock grazing is virtually its only food potential without the use of irrigation.

Rangeland is under constant climatic stress, and natural vegetation has developed that is compatible with the climate. Basically, the stress is the result of low soil moisture and a high evaporative demand.

Climatic stresses are more important than weather fluctuations in arid and semiarid rangelands. Whereas cropland conservation may be more susceptible to short-term abnormal weather fluctuations, droughts lasting several months followed by intense, erosive rains are a common rather than an abnormal occurrence on rangelands. These climatic fluctuations, those that are considerably longer than the day to day weather fluctuations, coupled with mismanagement, such as overgrazing have damaged rangelands all over the arid land world. Under such conditions, brush may replace grass and other forages which can lead to reduced livestock grazing capacities, inefficient use of precipitation and increased soil erosion.

Where cultivation is practiced, the amount of precipitation received during certain periods of the growing season is generally the most critical element. If precipitation is reasonably dependable from year to year and soils and supporting technology are adequate, the production of grain and other agricultural products will be reliable. Conversely, if precipitation is variable and erratic, agricultural production is likely to be correspondingly erratic unless supplemental water can be obtained.

PRECIPITATION VARIABILITY

Precipitation is measured at few sampling points. The spatial sampling error of precipitation is magnified by differences in precipitation gauge design and exposure and by catchment size. The standard precipitation station is not usually equipped to measure the physical properties of rainfall significant to soil erosion, such as the intensity of rainfall, raindrop size, drop size distribution, and terminal velocity of falling drops. The only observation routinely recorded is total daily precipitation.

Not only are standard precipitation data inadequate, but also analyses that attempt to characterize precipitation variability are limited. This section discusses the relationship between storm type and watershed size in terms of runoff, looks at the spatial and temporal distribution of storm rainfall and presents a brief discussion of an event-based precipitation model. The aim is to provide information for monitoring and analyzing the most important climatic variable, precipitation.

Storm Type and Watershed Size

Land management for agricultural purposes involves analyzing precipitation characteristics to determine its relation to either the infiltration or the runoff properties of the catchment or watershed. For example, runoff from small arid land watersheds is usually the result of the short-duration, high-intensity thunderstorm rainfall of limited areal extent. An example of such a storm is shown in figure 1. If the storm center would have occurred at some other location on the watershed, both the peak flow rate and the runoff volume would have been entirely different than what was recorded. Also, if the same storm occurred on a larger watershed with the same relative location as indicated in figure 1, the runoff would be less than from the smaller watershed.

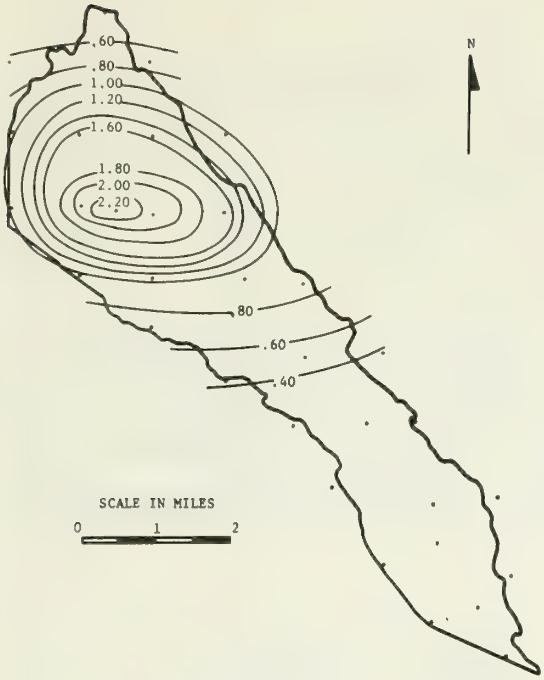

Figure 1.--Isohyetal map of a thunderstorm occurrence on an experimental watershed.

Some authors (Osborn et al., 1980) differentiate two thunderstorm types, airmass and frontal-convective. Generally speaking, the frontal-convective storm can cover larger areas, last longer and produce greater amounts of rainfall for similar durations than the airmass thunderstorm.

For the larger watersheds of river basin size, runoff events of any significance are usually the result of a sequence of events. That is, the watershed becomes primed or ripe for runoff with the occurrence in succession of several frontal cyclonic-type storms. These storms cover large areas, several hundred square kilometers or more, usually have durations of from a few to 24 hours and have average intensities of around 5 mm/hr. With the watershed soils being relatively wet, significant flow can occur in a river basin from a storm that produces only a small amount of runoff per unit area.

On rare occassions in the southwestern United States and central and northern Mexico, a storm usually originating as a tropical hurricane off the west coast of Mexico can result in flood-producing rains over large areas. These storms have characteristics that appear to be a combination of thunderstorm and frontal cyclonic-storms. That is, relatively large areas are affected, durations are long, but 15- and 30-minute intensities can be high.

Spatial Distribution of Storm Rainfall

An indication of the areal extent of storm rainfall is the depth-area relationship. While several such relationships have been proposed (Fogel and Duckstein, 1969; Meyers and Fehr, 1980 and Osborn et al, 1980) none of them appear to be universal. When statistical analyses are applied to network data the relationships or models explain no more than about one-half the variance. Thus, a more realistic model of spatial distribution would be one that contains both deterministic and random components.

While a given depth-area equation may or may not be suitable for all types of thunderstorm rainfalls, it is likely not to be adapted for the longer-lasting, more widely-distributed frontal cyclonic storms. An arithmetic mean or fraction thereof depending on watershed size appears to be the simplest approach for determining the spatial distribution of such storms for a given watershed.

Temporal Distribution of Storm Rainfall

Runoff-producing thunderstorm rainfall may last anywhere from 15 minutes to 2 hours or even longer. In many instances, the initial intensities are high, as much as 300 mm/hr for a 5-minute period, but taper off during the latter stages of the storm. Some storms, however, have their peak intensities occurring in the middle of the storm period with lower intensities during both the early and latter stages of the storm. Any attempt to come up with a simple relation between storm depth or intensity and time is doomed to failure. Storms of all types are generally too complex to be modeled successfully by a deterministic equation. Again, as in the spatial distribution, adding a random component to the deterministic one or using some other stochastic means may be more realistic in modeling the time distribution of rainfall intensity.

Event-Based Modeling

Probabilistic modeling of precipitation is a necessary adjunct to long-term planning of land management activities for determining both the economic and environmental consequences of such actions. This paper presents an event-based, stochastic approach to precipitation modeling, useful for simulating long-term records.

The use of event-based precipitation models starts with the definition of an event which is dependent on the intended use of the model and available data. For example, if the intent is to simulate the short-duration thunderstorm type of rainfall and only daily data are available, then an event may be defined as any day during the season when thunderstorms are apt to occur in which measurable rainfall was recorded. If the concern is for runoff from such storms, the event could be defined as one in which daily rainfall exceeded a

certain threshold value in excess of which runoff occurred. Similar definitions may be used for other storm types.

Return Periods

In design of water control structures, return periods for given amounts of precipitation are often needed. A return period in hydrology is the estimated number of years that on the average, a storm of a given magnitude or greater would occur in a given year. It is the reciprocal of probability, in that a storm with a 20-year return period has a 5% chance of being equalled or exceeded in any one year. Where records are available for perhaps 30 years or more, an annual maximum series usually suffices. Where records are limited, however, event-based models are usable with only a few years of data.

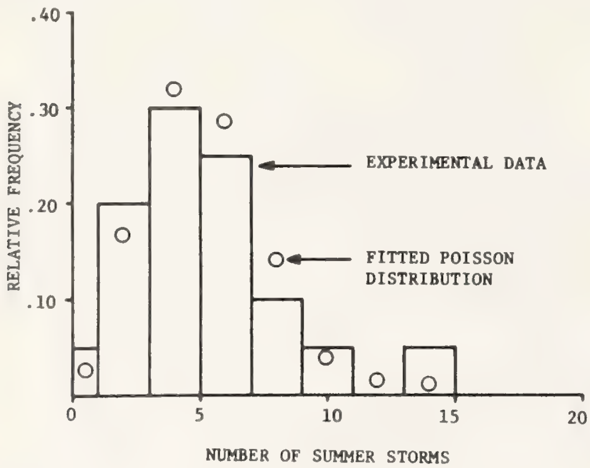

Figure 2.--Distribution of storm centers per summer season in 50 km^2 area.

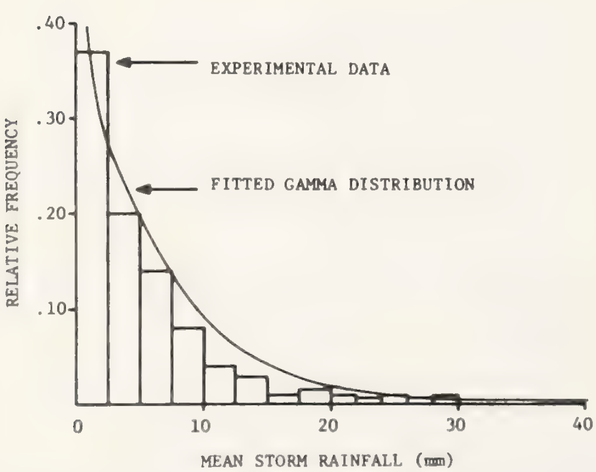

Figure 3.--Frequency distribution of mean thunderstorm rainfall for 20 km^2 watershed.

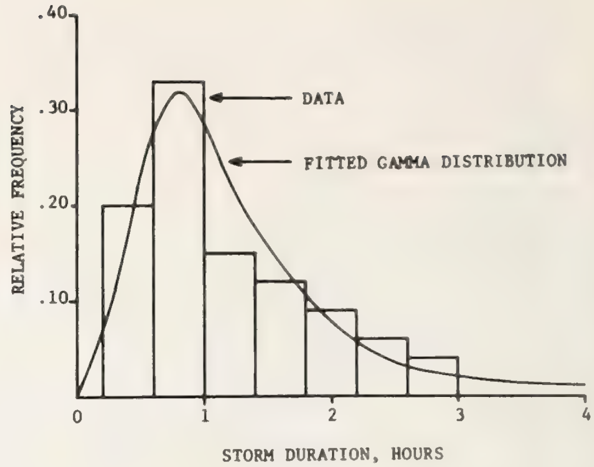

Figure 4.--Distribution of duration of thunderstorm rainfall.

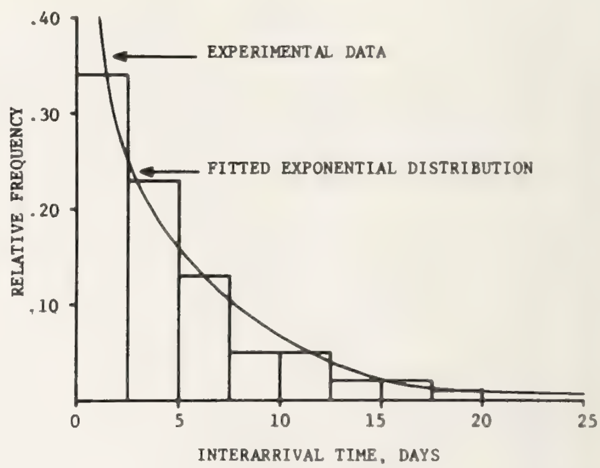

Figure 5.--Distribution of time between beginning of one thunderstorm and the beginning of next storm.

Such models require several basic distributions, e.g., number of events per unit time, precipitation depth per event, precipitation duration per event and interarrival times between events. Figures 2 to 5 illustrate typical histograms with fitted probabilistic distributions of these variables for southern Arizona's thunderstorm rainfall. It has been shown in earlier work that the return periods can be calculated from these distributions (Duckstein et al., 1972). This approach can also be used to incorporate the effect of elevation which has been shown to be a function of both number of events in a given period and precipitation depth per event (Fogel et al., 1972).

Seasonal Rainfall

It is sometimes desirable to determine the distribution of total precipitation during a season or a year. This can also be calculated from the distributions of number of events per season and precipitation depth per event (Fogel et al., 1974). Simply stated, the distribution for total seasonal rainfall is the sum of a random number (of events) of a random variable (rainfall depth per event).

Total seasonal rainfall, therefore, can come from almost an infinite number of combinations of number of events per season and rainfall depths per event. Using the distribution for interarrival time between events, Monte Carlo simulation can be used to generate a succession or sequence of seasonal or annual combination of events. This time series of events can serve as one set of inputs into a watershed model to produce a stream of outputs.

CLIMATE AND DECISION MAKING

Weather is a major element of uncertainty and risk in agriculture, specially in the drier regions. Of concern here is management activities to reduce risk, in a strategic sense, or respond or react to current weather in a tactical sense. Examples of strategic alternatives, which tend to be mainly preventive, are an irrigation system, check dams for erosion control, floodwater retarding structures and conversion of grain production to livestock grazing. Examples of tactical options, which may be preventive or reactive are time and amount of irrigation water and fertilizer application, time for pest management spraying and number and type of tillage operations.

This section presents an approach for integrating weather and climate fluctuations into a decision-making framework. The decisions or actions to be taken may be either strategic or tactical and are designed to reduce risk and uncertainty.

Managers differ in their willingness and ability to assume risk. Their convictions about uncertain events differ, but despite the large number of elements that enter into management decisions, the decision process is not unduly complex. In practice, the decisions tend to occur in branching sequences as shown in Figure 6 which is adapted from a National Academy of Science report (National Research Council, 1976).

The above deals only with the biologic response to climatic influences. However, each management decision has a consequence, not only biologic, but an environmental response as well. The amount of quality of water that comes off a watershed is an excellent indicator of environmental quality. In evaluating the effects of management inputs, both the biologic or economic response and environmental indicators such as water quality (including sediment) and amount must be considered.

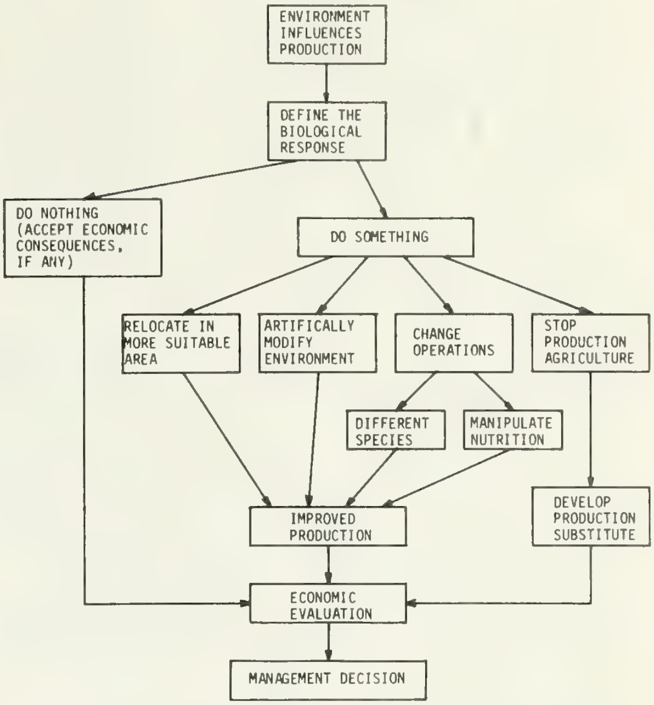

Figure 6.--Branching pattern of responses leading from environmentally induced production events to a management decision.

Figure 7 depicts the flow chart of a watershed system with a given set of physical properties and cultural and institutional aspects. These inputs, both climatic and man's actions, can be transformed into some form of useful vegetative production and into environmental indicators (sediment and chemical loadings in surface and groundwaters) by the use of existing watershed models. While the models may not be completely accurate, they do provide some indication of what might occur on a watershed with a given managerial action. Any such decision or action should be made considering a trade-off between production and environmental indicators. This evaluation should consider a full range of climatic inputs with many possible combinations of events. Simulating a long record, if one is not available, is one possible means for accomplishing this.

Simulation of climatic and management inputs to the watershed system is an excellent means for obtaining distributions of productivity and environmental indicators. This process is the technique that should be used in determining the climatic data needs for a given region. Data should be linked to the purpose for which it will be used. In this way, the economic value can be ascertained for a given set of climatic data.

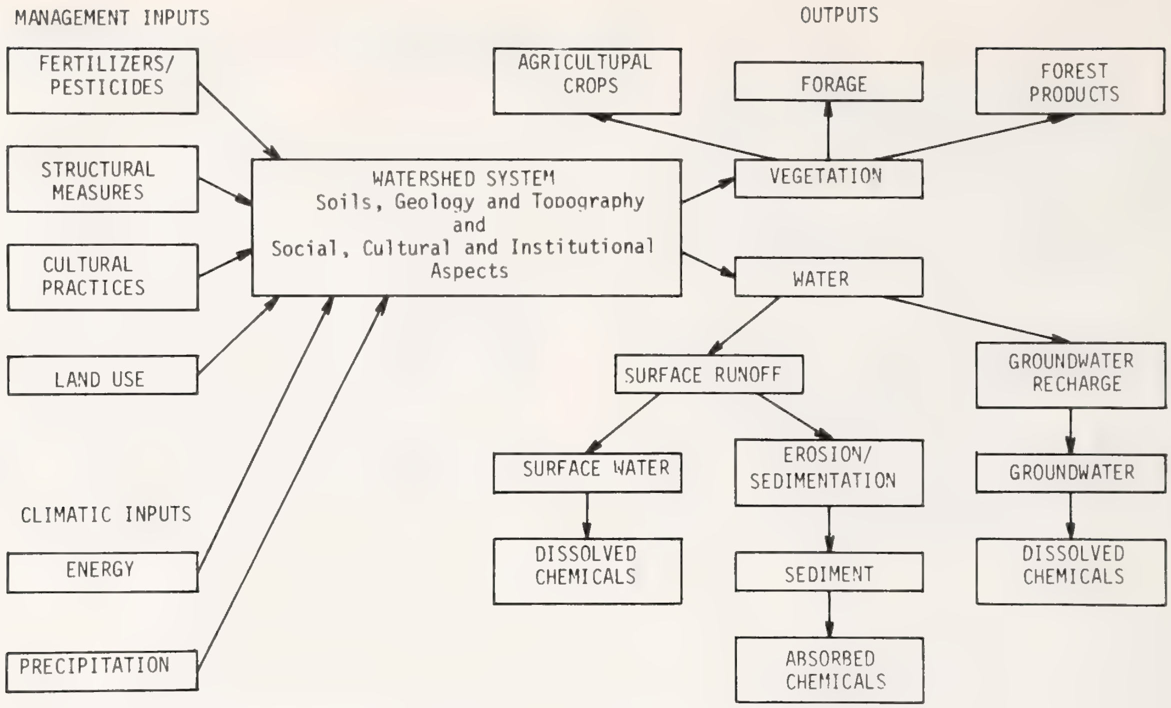

Figure 7.--Flow chart of system for evaluating effects of management inputs.

CONCLUSIONS

The following are the author's conclusions based on their experiences on climatic data needs for managing land and water resources in arid and semiarid ecosystems:

1. Climatic data requirements for drier regions differ than those of more humid regions because of greater variability in the arid areas.

2. Relatively dense networks of continuous-recording precipitation gages are needed to obtain spatial and temporal distributions of thunderstorm rainfall. Network density should be based on storm type and on hydrologic significance of the area and should be evaluated in economic terms.

3. Integrated research involving meteorologists, climatologists, hydrologists and agriculturists should be stimulated. Problem areas for such efforts include more accurate seasonal, annual and long-range climate forecasts; wind and water erosion; defining basic functional responses of crops and animals to weather and climate; and a fuller understanding of how weather and climate, crops, pests and pest control interact.

4. Climatic data, primarily precipitation, should be processed such that the event-based analyses are readily accomplished.

5. Event-based data and models are recommended because they describe phenomena in a natural way, are more suitable to evaluating man's attempt at modifying arid land ecosystems than the conventional equal-time-interval data, and finally, the approach lends itself to the management of natural resources for optimal benefit.

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RESUMEN

La administración o manejo eficiente de tierras, ya sean áridas o no, puede considerarse como la evaluación de un intercambio o trueque entre la productividad y la conservación de los recursos naturales. En este ensayo, la productividad de las tierras áridas se refiere a su capacidad para la producción sostenida o continua de productos alimenticios y de fibras mientras que la conservación de los recursos naturales considera tanto la disponibilidad de la tierra y del agua como la protección y el engrandecimiento del medio ambiente.

Con frecuencia se ha culpado a las actividades pastorales y agrícolas del hombre en las regiones más áridas del mundo de ser responsables de la propagación de las condiciones desérticas. Puede señalarse, sin embargo, que dichas acusaciones se hacen sin tener en cuenta otros factores que originan estas condiciones, como las influencias climáticas. Los administradores de tierras necesitan datos que les permitan emplear técnicas y procedimientos que sostengan una producción consistente con la degradación que limita el medio ambiente.

Reconociendo que las tierras áridas muestran grandes variaciones climáticas, este ensayo se concentra en la variabilidad de precipitación en el tiempo y el espacio y en modelos de manejo de tierras que utilizan aportaciones climáticas para generar los rendimientos deseados, como producción de agua y de vegetación.

La variabilidad de precipitación se observa como un indicador de fluctuaciones climáticas. En cuanto a las aguas de desagüe, la relación entre los desagües causados por las tormentas y los desagües causados por las cuencas, un factor primordial en la variabilidad de precipitación, tiene que entenderse para calcular y predecir ya sea el rendimiento del agua o el desagüe que causa inundaciones. Un modelo de precipitación basada en un suceso o evento sirve de aportación a un sistema de cuencas para evaluar el trueque o intercambio entre la productividad y el medio ambiente. Se sugieren modelos de cuencas para transformar las aportaciones climáticas y las decisiones administrativas en producción vegetativa y en tales indicadores ambientales como el rendimiento de agua y de sedimento y la calidad del agúa.

Los autores concluyen que la precipitación altamente variable de las tierras áridas requiere una red relativamente densa de indicadores de precipitación facilitando datos continuamente para su análisis. También se recomiendan datos y modelos basados en un evento o suceso porque describen fenómenos de una manera natural, y porque son más adecuados para la evaluación de los esfuerzos del hombre para modificar los ecosistemas de tierras áridas que los datos convencionales tomados a intervalos iguales de tiempo.

Logistical Inventory Problems in Tropical Areas[1]

Andrew J. Nash[2]

Abstract.--Logistical problems of transportation and supply of field crews in tropical inventory operation are discussed. The planning required to maximize productive field crew time are outlined and an example of a large tropical inventory using road, water and helicopter transport is included to demonstrate logistical planning procedures.

Webster's New International Dictionary, 1954, defines logistics as:

> "... that branch of the military art which embraces the details of the transport, quartering and supply of troops in military operations."

Is this military definition any different from the operation of a tropical forest inventory? or of any inventory of natural resources for that matter?

A tropical forest inventory must be planned as carefully as a military operation to maximize productive time for the collection of field data. It becomes even more important to pay attention to detail when the forest inventory is to be carried out under adverse conditions of terrain, climate and accessibility as in many areas of the tropical world.

It must be assumed that an inventory planning team which includes a statistician, forest manager, inventory specialist, data processing expert and others, has met many times to devise the sampling scheme, has field-tested the data forms, devised code lists for the data, made trial runs with dummy data to test the computer programs and held training sessions for field crews to ensure that there is consistency in the collection of data. At this point, logistics becomes the key to the success of the entire inventory operation. How are the inventory data to be collected in the most efficient manner? what contingencies have been made to deal with emergency situations? where are the base camps to be located? what means of transportation can be used? vehicle, boat or helicopter? or combination of all three? if there is an extensive river/stream network, how far is it navigable for small boats? with helicopter transport, are there sufficient numbers of natural openings where a helicopter can land or must heliports be constructed in dense jungle locations? how does the field inventory leader communicate with the area headquarters office and with field crews and helicopter pilot? It is not difficult to think of other situations in the field where logistical problems assume major proportions.

In many workshops and conferences dealing with tropical inventory problems, a picture of dense forests with a practically impenetrable underbrush comes to mind. The areas generally have low population density and a sparse road network. There are many such areas throughout the tropics; however, the inventory area need not be forested. It could be an open savannah type more suitable for grazing of livestock or an arid, desert location with very little vegetation. This paper is not concerned with the measuring and processing of field data but with the most efficient method of placing field crews as close to the sampling points as possible -- the logistics of the operation.

First and foremost - PRIORITY NO. 1 - the logistics planner must know the area in some detail! Information is essential regarding the road system, extent of navigable rivers and streams, location of villages, the general topography of the inventory area and detailed topography of areas within camp boundaries, the location and type of forest cover, location of natural openings and agricultural land and so on. Where does this information come from? The inventory planner must examine all sources of data -- aerial photographs, topographic maps and consult with many government officials. Some maps are quite old and out-of-date but it is always easier to make a revision of an old map than to draw one from the beginning.

Some tropical areas are not covered by topographic maps or aerial photographs. The next alternative is to obtain aerial photographs of the area and to make an uncontrolled mosaic (Nash 1979). Using the overlapped portion between suc-

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[1]Paper presented at the Arid Land Resources Inventory Workshop held in LaPaz, Mexico, November 30 - December 6, 1980.

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cessive photographs or by matching and cutting, adequate maps can be drawn from the mosaic to show the necessary information. Depending on elevation differences within the area, the mosaic (and map) will have some scale differences, but the advantage of a map is far greater than problems caused by scale differences. The production of professional topographic maps by the host government cartographic service or by contract should not be over-looked. If time and money are available, this type of map is far superior; however, it takes approximately two years to produce a professional topographic map from the date of the photography and most inventory projects cannot afford to wait this long for a map. Time and money are very powerful constraints in an inventory project and often, it is preferable to accept a lower quality map made from a mosaic.

Some inventory projects do not include funds for aerial photography, although it is difficult to conceive a major inventory of natural resources which relies exclusively on field data. However, assume that there are no maps and no photo coverage and that the logistics planner requires area information. A possible solution is an aerial reconnaisance, sketching the terrain features while flying a systematic pattern across the area. This is not easy to do and the temptation is to ask the pilot to fly at a lower altitude because the observer becomes interested in the actual forest types and other land uses, losing sight of the original objective -- to obtain a map of the total area. This is truly a case of "... not being able to see the forest because of the trees."

At this point in the planning process, there is some type of map of the inventory area. This is the starting point for planning the travel of field crews to the sampling points. Examine the sampling scheme and become familiar with the reasoning behind the adoption of a particular sampling system. It may be a random allocation of sampling units (Nash 1973, Dias 1975) to determine a precise value of sampling errors, or it may be a systematic distribution. Some inventories of tropical forested areas have used a road as a base line and a systematic spacing of lines at right angles to the road, with the length of the lines being randomized, or a fixed line length with random spacing between the lines. In tropical inventories involving long, arduous travel between sampling units, a cluster type of sampling is generally preferable because the sample statistics take into account not only the variation between clusters but also within clusters. There are advantages and disadvantages to both a random and systematic allocation of sampling units (UN/FAO 1973) but wherever a one-stage sampling is feasible, a systematic distribution of the sampling points is highly desirable. An important rule in cluster sampling is that there should not be more recording units in a cluster than can be measured by a crew in one day's work <u>including return travel time from the base camp</u>. This restriction places a heavy responsibility on the logistics planner.

For efficient field operation, field crews must be placed as close to the sampling units as is practically possible. The method of transportation depends on local conditions of terrain and accessibility (Nash 1976). The most simple, direct way is to transport the crews by vehicle, resulting in the highest rate of return of productive field time. Road transport is not without its problems, however; problems of service and maintenance of the vehicles, fuel supply and road conditions must be considered. Alternatives to road transport are:

1. <u>river/stream travel</u> - In many areas of the tropical world, boat travel is the only means of access to remote areas. It is the least productive method of transportation because it is slow, but in some circumstances, productive time must be sacrificed. The logistics planner <u>must</u> have an accurate map of the navigable rivers and streams in order to plan effectively. He must know the location of shallow areas, waterfalls and/or rapids to budget the field crew's time properly.

A good example of the use of river transport is the UN/FAO Forest Industries Development Project in Sarawak, Malaysia. Hindley (1971) reported that a number of sampling units could only be reached by boat and foot travel. For a total of 96 clusters (each with nine recording units), it took an average of 8.9 crew-days to obtain the measurements on a single cluster. Of this time, 3 crew-days were spent in establishing and measuring the inventory sample and the remainder was spent in travel, brushing out or clearing survey lines, packing supplies and days of rest. The average distance from the boat to sampling unit was approximately one mile (1.6 km) which indicates that the navigable river network was rather extensive.

2. <u>helicopter transport</u> - The use of helicopters to transport crews must not be overlooked or dismissed as being too expensive. There are many situations in which helicopter transport is definitely cost-effective. Comparing the productivity between ground transport and helicopter travel under the most difficult conditions in Sarawak resulted in a decrease in time from 12.9 crew-days/sample to 6.8 crew-days/sample <u>for the same cost per sample</u> (Hindley 1971). The helicopter costs included wages and allowances for the field crew members, heliport clearing costs, helicopter transport at a fixed hourly rate ($360/hour), pro-rating the cost of positioning the helicopter in the inventory area from its home base and bringing food and fuel to the base camp. An interesting technique used in Sarawak was to increase the height of the helicopter skids so that the tail rotor was at a greater height from the ground. This simple operation decreased the time required for crews to clear a suitable heliport area.

Helicopters have also been used very effectively in the reconnaisance inventory of the forests and other natural resources in the tropical rain forests of the Amazon River basin (SUDAM: Project Radam 1974).

In arid areas where there are extensive open areas or where agriculture is a major activity, helicopter transport of crews will result in an even greater saving of non-productive time.

The preceding has focussed on methods of transporting field crews and supplies to remote sampling units under difficult accessibility conditions. No base camps have yet been set up and no field crews have been sent out to start collecting data. Field work does not start until the logistics planner has taken care of all foreseen eventualities that could occur during the inventory operation.

A major consideration in tropical inventories is COMMUNICATIONS:

1. between the area headquarters and the field base camp(s) - Two-way radio equipment is important to maintain a smoothly-running operation. There are day-to-day problems which must have immediate answers; there are emergency situations which require instant action. The field camp leader must have solutions and communication with the area headquarters will keep all administrative personnel informed.

A fixed time schedule should be established for daily communication regardless of whether there is important news or not. Emergency situations require a special signal to alert the area headquarters of an urgent message.

2. between base camp, field crew and helicopter pilot - A less sophisticated radio communication system can be established because distances are usually shorter than between the base camp and headquarters. The need for some line of communication is primarily to take care of emergency situations - accident or illness requiring transportation for medical assistance. Another occasion in which communication is extremely beneficial is if the helicopter malfunctions and is stranded in an isolated area. Without radio contact, not only is the helicopter pilot stranded but also the field crew which is relying on the helicopter to pick them up at the end of the day's work.

EXAMPLE OF LOGISTICS PLANNING FOR A LARGE TROPICAL FOREST INVENTORY

A hypothetical tropical area will be used to illustrate the techniques of logistics planning in the location of base camp location and transportation to the sampling units. Loetsch, Zohrer and Haller (1973) recommend the establishment of a camp unit system for the collection of field data from clustered sampling units and this idea will be followed in the example.

Figure 1 shows an inventory area with the navigable rivers and streams. Specific information about the area is:

Total area of project - 11,500 square miles (29,785 square kilometers)
Area of forests - 65% or 7,500 square miles (19,425 square kilometers)
Topography - Gently rolling, not mountainous
Transportation available - Trucks, small boats with outborad motors, 6-seater helicopter
Sampling design - Systematic allocation of clustered sampling units space 3 miles (5 km) apart. Each cluster consists of 6 units of record.

Inventory area is adapted from UN/FAO Forest Survey Report (1970)

Figure 1. Inventory area showing navigable streams.

Figure 2 shows the same area with the addition of the road network, and forested areas which are to be sampled.

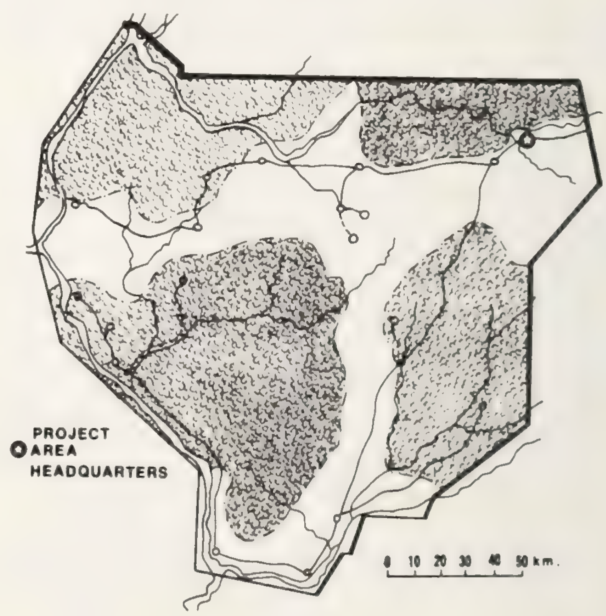

Figure 2. Inventory area with road, villages and forested area.

Figure 3 is an enlargement of the southwest forested area; it shows the road, river/stream system, villages and the systematic location of 200 sampling unit locations.

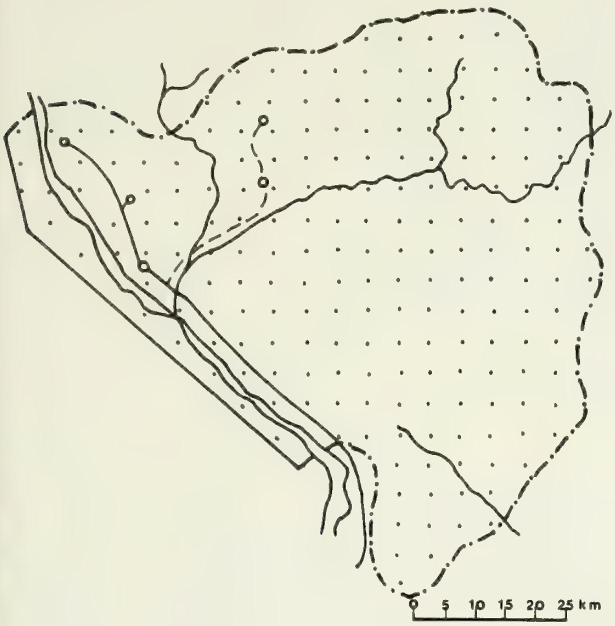

Figure 3. Southwest inventory area with sampling unit locations.

The logistics planner now has to make a decision regarding the location of base camps and the sampling units which can be reached from the road and water access routes. The remainder of the sampling units must be reached by helicopter transport.

In areas with dense undergrowth which has to be cleared by machete, the maximum distance which can be travelled from a road or river to a sampling unit cluster is about 2 miles (3.3 kilometers) and return to the road (or river) at the end of the day. Advantage can be taken of the systematic design by using previously-cleared access routes to reach further clusters. A point is reached where travel time becomes excessive and helicopter transport must be used to reach the more remote clusters. On the assumption that the first assault on the jungle results in a 3 kilometer distance (Dias 1975) and that an additional 3 kilometers can be cleared, a band of sampling units 6 kilometers from the access routes can be measured. Not all forested areas are alike as far as difficulty of access and travel are concerned and in some cases, a 10 kilometer distance may be a practical limit for foot travel.

Figure 4 shows the probable limit of distance from road or water access routes to sampling units and the location of base camps either close to villages or along the access routes.

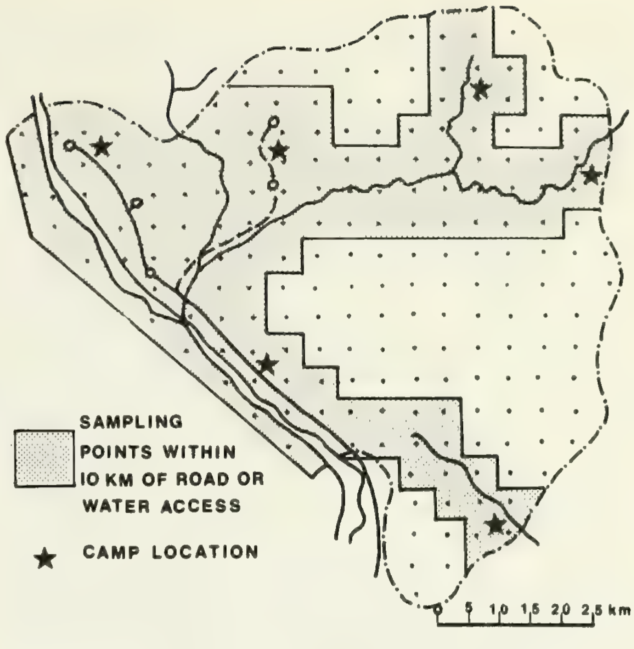

Figure 4. The southwest forested area with sampling units within a 10 kilometer distance from road and water access routes.

The location of heliports depends on natural clearings in the forest. If there are none within workable distance to sampling units, a heliport must be cleared by manual labor. The size of the clearing is dictated by the type of helicopter, its loaded weight and atmospheric conditions, particularly temperature. Hindley (1971) describes heliport construction techniques which have been successful in dense jungle forest conditions.

Heliport locations have not been shown in Figure 4 because clearings are not indicated. An overlay of the sampling unit locations on a mosaic of the inventory area will show possible heliport sites. Figure 4 shows that a total of 84 sampling units must be visited from heliports and, if 10 sampling units can be measured from one heliport, 9 heliports must be cleared.

If helicopter transport is not available, the field work will take considerably longer and the cost of obtaining the measurement data could be more than doubled.

Because the inventory operation is a service function designed to provide data for decision-making at a high level, and because the act of measuring the trees does not increase their value, it is important for the logistics planner to achieve the objectives of the inventory at the lowest possible cost.

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RESUMEN

Los problemas logísticos de transporte y abastecimiento del equipo de campo en la operacion de inventario tropical son discutidos. El planeamento necesario para el provecho máximo del tiempo productivo del equipo es formulado y un ejemplo de un largo inventario tropical usando carretera, agua y helicoptero de transporte se incluye para demonstrar los processos del planeamento logistico.

Benefits and Costs of Natural Resource Inventories of Arid and Semi-Arid Lands[1]

Miguel Caballero[2]

Abstract.--This paper emphasizes some of the major difficulties involved in evaluating costs and benefits of arid land resource inventories. The limitations of tagging economic value to inventory goals is discussed. The need for economically efficient multi-resource inventories as a basis for social welfare programs in developing countries poses an important challenge to natural resource specialists.

INTRODUCTION

Reference to arid lands implies consideration not only of a vast area of a natural resource, but a wide variation of habitats and natural conditions as well. There is, however, a common denominator that invariably comes to mind, and that is the water restraint. Whether measured in terms of amount of rainfall, humidity indexes, or evapotranspiration values, available water is basically the limiting factor.

For many years, arid regions were considered largely as valueless resources, except for those endowed with oil and mineral reserves. But things are changing radically. In a world of greater resource scarcity and exponentially growing population, arid lands are becoming more important each day.

It is evident that, if properly managed, arid lands offer important potentials for food, fuel, wildlife, recreation, and wilderness values. In this context, natural resource inventories will be more relevant as a basis for sound decisions on resource utilization. There is, however, a need to revise currently used methodologies in view of their present costs in relation to benefits. This paper attempts to review some of the benefit-cost relationships of arid-land resource inventories as they have been currently applied.

[1] Paper presented at "Arid Land Resource Inventories: Developing Cost-Efficient Methods", an international workshop. (La Paz, Mexico, Nov. 30-Dec. 6, 1980).

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SOME OBJECTIVES OF ARID-LAND RESOURCE INVENTORIES

A discussion of benefits and costs of arid land resource inventories can be facilitated if a general framework of the different kind of objectives is established first:

For National Resource Utilization

Most frequently, the interest centers in determining the level of potential harvesting of renewable resources. Such is the case with inventories conducted by national or local governments and private firms to evaluate sustained yield levels of outputs from arid-land commercial vegetation. To cite an example, different kinds of organizations have been interested in estimating the size, distribution, and annual yield of "candelilla" (Euphorbia antisyphilitica), "lechuguilla" (Agave lecheguilla), and species of palms (Yucca spp) in northern Mexico.

To Generate Income and/or Create Local Jobs

Particularly in developing countries (precisely where most of the world's arid lands are located), the inhabitants of arid and semi-arid regions have frequently been classified as the most indigent population strata of the world. White (1966) established that "among the countries lying wholly within the arid zone, the GNP per capita is everywhere less than US $125, considerably below the mean of $200 for the world's population." It has long been recognized that living conditions in arid regions are usually very far behind those of urban centers. These circumstances justify the efforts of governments to increase the number of jobs and generate additional income from those lands.

It is evident that the net result of such endeavors depends, to an important extent, on the nature and efficiency of the resource inventory. Information from inventories of this nature can be useful for several income-generating

activities such as: (a) creating new handcrafts or intensifying existing ones (an interesting example in this respect is provided by the "seris," a native-Mexican population from Sonora, Mexico, which for years has been depleting the natural population of "palo - fierro" trees - Olneya tesota - for wood carving handcrafts in northwestern Mexico); (b) developing recreational sites; (c) establishing new industrial settlements and (d) opening lands to agriculture and livestock production.

To Establish Rural Development Programs

Before the development of an irrigation project, the state or federal government should have precise information on land use, soil types, water sources, topography, and other types of resource information. Most of the programs to establish some kind of regional infrastructure require the support provided by resource inventories.

To Protect Natural Resources

Natural resource inventories provide valuable information to preserve different kinds of plant and animal species. Some examples are: (a) protecting endangered species; (b) protecting grasslands from overgrazing; (c) protecting natural populations from fires and human disturbance, in general, and (d) preserving the biological chains and interactions between species of wildlife and plants. Resource inventories are also needed to determine the progress of desertification and subsequent control measures.

To Evaluate Multiple Use of Lands

Arid lands offer a variety of present and potential uses: agricultural and livestock production; renewable resource production; non-renewable resource (minerals and oil) production; recreation; wilderness, etc. Multi-resource inventories can be very useful to determine the most efficient output mix.

To Assess Resources on a Nationwide Base

As part of the overall objective of determining the natural reserves, several countries have established national services for a continuous evaluation of some of the most strategic resources. The results thus obtained are used, among other purposes, to determine policies relative to resource allocation and use. The governmental services that some European countries have established to estimate the dynamics of the forest resource could be categorized in this classification.

BENEFITS AND COSTS

Economists frequently emphasize the complications involved in trying to identify the benefits and costs of natural resource projects. Some of the implications involved (Gray and Huszar, 1979) are:

(I) Pervasive unintended consequences of resource allocation decisions.
(II) The societal, as opposed to the individual, view of resource issues.
(III) The central concern with resource use over time.

A proper consideration of the above factors should be reflected in the inventory objectives and working procedures. It is clear, for example, that if the purpose of the inventory is to allocate an irrigation system to increase agricultural production in an arid region, a reduction of natural habitats for plants and wildlife can be expected as a consequence. In these conditions, a sound resource inventory would provide information on natural populations most likely to be affected, and expected impact on local inhabitants who currently benefit from routine use and consumption of those populations.

In opposition to the Pareto improvement criterion, whereas a set of farmers would benefit from the establishment of the new water system, another group of rural inhabitants would be affected through the reduction of some of their sources of income.

Time becomes another source of main concern, given the existing limitations to forecast long-term costs and benefits. To my knowledge there is no inventory procedure as yet applied to arid lands that can be successfully used to estimate the wide interactions of long-run project costs and benefits.

3.1 Benefits.

Not much can be found in the world-wide literature about the economic benefits of natural resource inventories as applied specifically to arid lands. This is partially explained by the fact that not many inventories have been carried out to assess natural resources of arid lands. Instead, most efforts have involved ecological descriptions (Harris, 1972), aerial reconnaissances vegetational patterns of distribution (Mooney and Harrison, 1972), soil surveys (Gelderman et al, 1972), water studies (Hadad, 1973), or some other kinds of rapid, low-cost assessments.

A major cause of the apparent lack of interest in true arid-land resource inventories seems to be the limited economic returns usually expected from those lands. Due to poor growing conditions, populations of plants and wildlife from such habitats are usually characterized by small biomass, small size, and low frequency--even though some species may have a high unitary value. Except for a few specific patches, under the most favorable site indexes, forest trees are scarce and frequently lacking in arid lands. The few species adapted to such conditions are

usually of poor form, limited size, and slow rate of growth, as evidenced by most pinyon pines (Pinus spp) and junipers (Juniperus spp) in America, cedars (Cedrus libani) in Asia, or Podocarps (Podocarpus) in Africa. Because of these circumstances, regular forest inventories don't appear economically justifiable.

In some American continent arid lands, most of the natural resource commercial output is afforded by herbs and shrubs, which provide a variety of products with open or restricted market value. Depending on the nature and magnitude of this natural endowment, the contribution of those resources to the local economy may be substantial. Additionally, some trees provide wood for domestic use and fuel consumption, playing an important role in rural life. Wildlife is important in that it supplies an important source (and sometimes the unique source) of protein for rural populations. The seasonal availability of some natural grasses makes domestic animal raising possible.

It is thus evident that evaluating benefits from resource inventories of arid lands is not an easy task. The fact that some important outputs have a pecuniary value in open markets, some others do only in restricted markets, and still others have no monetary value at all, creates further complications. To cite an example, we might question what procedure would be proper to evaluate the economic benefits of an inventory to study a wild population of "mountain sheep"--"borrego cimarron" (Ovis canadensis) in Baja California, Mexico, assuming the species is endangered and the purpose of the inventory is to formulate protective policies. By the same token, similar questions could be raised in connection with resource inventories to establish new wilderness in Colorado or preserve scenic values in Utah, U.S.A.

3.2 Costs.

The costs of inventories are closely tied to the objectives. The nature of the project specifies how elaborate and precise the information required should be, and hence will determine the overall inventory cost. Accordingly, it is reasonable to expect higher unit costs in the case of an inventory to utilize specifically a limited set of resources in a given locality than in another case where the inventory is intended to obtain a broad estimate of resources as part of an overall national assessment. The nature of the population to be dealt with and the level of precision required are also important determinants of cost.

As frequently occurs in the majority of natural resource inventories, field work is perhaps the costliest component of most arid-land inventories. The highly dispersed and yet relatively uniform nature of several arid-land biological populations, however, makes it feasible to reduce field work at low levels. A preliminary delimitation of the resources of interest on aerial photographs may prove to be highly advantageous. This approach was used by the Mexican National Forest Inventory in conducting the forest inventory of the State of Baja California Sur (Direccion General del Inventario Nacional Forestal, 1966). All arid regions in the State were first identified on aerial photographs and marked on detailed maps. Further, each arid zone was thoroughly studied by both air (helicopter) and land reconnaissance. The precise location of each vegetational type was carefully registered on the proper photographs. Field work was limited to a low sampling intensity of only those few stands possessing trees with present or potential value. Similar criteria were used to evaluate the forest resources of the coastal semi-arid lands of Jalisco, Colima, Guerrero, and Oaxaca.

Arid-land resource inventories in developing countries pose serious technical and social problems which lead to complexities in cost and benefit estimation. To cite a specific case, some thousands of Mexican peasants inhabit the arid lands of the northern states of Coahvila, Nuevo Leon, and Tamaulipas. A significant share of their income originates from harvesting some natural vegetation, mainly "candelilla" (Euphorbia antisyphilitica) and "lechuguilla" (Agave lecheguilla). The first provides a highly valued natural wax. From the foliage of the second, a multipurpose fiber is obtained. To the concern of the federal and state authorities, it has been observed that those natural populations are being gradually destroyed. This destruction is adversely impacting the local inhabitants. They now have to devote greater efforts to locate more distant, progressively smaller populations, and to transporte the valuable output.

The Mexican Subsecretariat of Forestry and Wildlife has recognized the need of an inventory to estimate the size, distribution, and growth of those two and several other important species in the arid lands of Mexico. Nevertheless, numerous problems have delayed implementation of the project. As contrasted to standard forest inventories, where working procedures have been routine for years, in this case, many doubts have been exposed. Given the nature of the populations and their unusual pattern of distribution, what type of sampling scheme can accomodate both species economically and efficiently? If wax is the only output of economic interest for candelilla, what kind of measurements, how many, and where should they be taken in the field to estimate wax content reliably?

To extract the wax in the field, even from a few plants, would be time consuming. What kind of direct "easy to do" measurements could be taken, under the assumption that they should be highly correlated with wax content? Similar questions could be raised for lechuguilla and other species.

The aims of such an inventory would be the provision of information to (a) develop a program for increasing future regional income on a

sustained basis; and (b) structure policies to protect and expand the now endangered populations. The resource inventory should thus generate reliable annual estimates of population dynamics, such as natural regeneration, mortality, plant growth, wax yield (for candelilla), and foliage production (for lechuguilla). Given these requirements, what would be efficient criteria for measuring growth, foliage production, and other needed variables? Could the principles of CFI be successfully applied to our non-wooded base populations? If so, what variants should be implied?

Candelilla and lechuguilla, are only two examples for discussion. Several other populations of commercial value--including wildlife--for the inhabitants of arid lands, with their own specific problems, can be cited as well. Examples include jojoba (Simmondsia chinensis), whose oil has a significant industrial demand; the cactus plants used for forage and human consumption, such as nopal (Opuntia spp); different species of palms which supply inputs for a range of handcrafts; guayule (Parthenium argentatum), of increasing importance for rubber production; and even plants with high ornamental value such as cirio (Idria columnaris). Our colleagues with experience in Asian and African arid lands could also cite similar examples.

The situation for forests in dry lands, is not much different from what has already been expressed. Pinyon pines and junipers form one of the most frequent conifer associations in the American lands of the northern hemisphere. When conditions are somewhat more favorable, some other more demanding species, such as Pinus ponderosa, Pinus jeffreyii, and P. arizonica, among others, are also present. Most of them have poor form and growth rate is low. The costs of inventories for these lands vary widely. The U.S. Bureau of Land Management provides an average figure of $0.08 per acre. There is a broad feeling among experts that such an average cost is high, since an average aggregate net benefit of only $0.06 per acre brings the benefit-cost ratio to less than unity. As a consequence, present efforts of the U.S. Forest Service and the Bureau of Land Management to reduce inventory costs seem justified.

4. THE CHALLENGES

Resource inventories for arid lands imply the study of complex, relatively little known populations, facing the problem of low economic returns. The main difficulty seems in devising adequate inventory procedures at low costs.

The fact that numerous problems threaten arid-land environments all over the world, increases the need for a periodic and continuous assessment of these lands. Increasing salinity, overgrazing, fires, pollution, and human disturbances (establishment of new residential areas, additional land openings to agriculture and livestock production, detrimental effect of recreation, natural resource depletion, etc.) are some of the factors contributing to arid land expansion. The fact that several governments of developing countries are establishing development programs for their arid lands emphasizes the need for multiresource inventories. The magnitude of the problem and its consequences strongly justify the establishment of a continuous system of assessment of resource dynamics in arid lands.

Inventory specialists are challenged to devise a system that would sustain the required level of precision at the lowest expense. This challenge should be overcome by the resource specialists, given the intricate interaction of complex resources which should be evaluated under the restraint of inexpensive inventory schemes. State and federal authorities are anxious to have reliable and sufficient information to determine future land use allocations that reconcile both economic efficiency and rational use of resources. Unfortunately, most of this information is still lacking in the dry regions of Latin America, Africa, and Asia.

Inventories oriented to non-market outputs (intangibles) also pose many questions and problems. For example, the criterion to determine maximum expense allowance of inventories to establish recreational areas or wilderness is still a matter of controversy. By the same token, the costs of adequate inventories to manage and protect endangered species, or to reestablish productivity of deteriorated habitats, are highly speculative. Despite scattered efforts in this respect, there is a strong need to set standardized criteria and define procedures, as for example, to calculate inputed values, shadow prices, and opportunity costs, among many others.

The technological breakthroughs that remote sensing has experienced in recent years has provided new tools for a better understanding of arid land resources with a minimum of direct exploration (Omino, 1973; Schumann, 1973). This field offers one of the most important potentials to reduce costs of future inventories on the basis of increased speed and enhanced efficiency. It has been suggested that remote sensing provides the optimum result when applied as a multi-stage, multi-spectral sampling utilizing aircraft, spacecraft, and ground observers (Colwell and Carneggie, 1971). It seems reasonable to suggest that governments of nations in the world's arid belt obtain as complete and good photographic coverage of their arid lands as possible.

The application of economic and mathematical tools to resource optimization with the aid of high-speed computers is receiving increasing attention, and enhances the need for efficient and low-cost continuous inventories (O'Connell, 1972; Coronado Resource Conservation and Development Project, 1973; Brown, 1971).

Some of the questions and doubts posed in this paper have long been the subject of

research. Some others are still in the phase of future research planning. But it appears that, in a world of increasing resource scarcity, arid lands are not far from becoming an alternative future door to economic growth. When that moment arrives, resource inventories should provide the needed information effectively, precisely, and economically. There is no doubt that resource specialists still have a long way to go along the research path to inventory the arid and semi-arid lands of the world.

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RESUMEN

La presente ponencia destaca algunos de los problemas más importantes involucrados en la evaluación de costos y de beneficios de los inventarios de recursos naturales de zonas áridas. Se discuten las limitaciones que existen para poder asignar un valor economico a cada una de las metas del inventario. La necesidad creciente de contar con inventarios de recursos múltiples que sean eficientes desde el punto de vista económico, como una base para el establecimiento de programas de bienestar social en países en proceso de desarrollo, establece un importante reto a los especialistas en recursos naturales.

Standardization, Coordination, and Cooperation Among Resource Activities[1]

William J. Pulford[2]

Abstract.--Coordination and cooperation between resource activities requires inventory design and planning which is thorough and adequately tested. In particular, good inventory design requires knowing about the use of the data, inventory objectives, data elements, definitions, standardization of terms, population characteristics and a host of other items. In the design process natural resource specialists must be prepared to work together for common solutions.

INTRODUCTION

In this paper I plan to cover two aspects of coordination and cooperation between resource activities. First are the items that should be considered in design of an integrated system of inventories involving several resource activities. The second is the actual standardization coordination and cooperation, needed between resource activities to carry out a multiple-use inventory.

My discussions are based on BLM experiences in designing procedures for coordinating inventories and the actual on-the-ground inventories. BLM inventory procedures are based on a comprehensive planning system that requires preplanning. The system also requires significant coordination between resource activities, a definition of problems, and discussions with managers, before any on-the-ground work is started. We've found the process to be very effective if the inventory and planning process is well thought out in advance; and if we have comprehensive public participation with users and interested groups. We have not solved all of our problems, however, I believe we are on the right track. Our major problem areas are in the design of the inventory techniques that can recognize regional differences, the levels of inventory and the coordination required for a cost effective approach to an integrated system of inventories. I discuss these areas in detail below.

DESIGN OF COORDINATED INVENTORIES

The Bureau of Land Management's organic act (Public Law-579) requires periodic inventories of the forest and range resources. The act calls for objective information and a continuous inventory of all public lands and their resources, and other values (including but not limited to outdoor recreation and scenic values), giving priority to areas of critical environmental concern. The inventory is to be kept current to reflect changes in conditions and to identify areas of critical environmental concern. Based on this law the Bureau is developing an integrated system of inventories which require designs that recognize extensive coordination. Designs that require coordination among resources are expensive and time consuming. It requires plain hard work and a group of people dedicated to making it work, both resource specialists and managers.

In the design of any coordinated resource inventory, several items must be considered. They are as follows: The design must recognize a common inventory unit based on political or administrative boundaries. It must be coordinated with the underlying basic resource mission of the agency and recognize the needs of planning and the management decision process. It does little good to define an inventory unit that is mismatched with your decision process. For BLM, as an example, we manage on 100's or 1000's of

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[1]Paper presented at the Arid Land Resource Inventories Conference, LaPaz, Mexico, Nov. 30 - Dec. 6, 1980.

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acres - that's how our decisions are made. If we define small inventory units (say 1 acre) all we are doing is being needlessly specific - wasting manpower and time. If inventory units are to be building blocks, the smallest administrative unit corresponding to management decisions should be designated as the inventory unit.

Next, the design must, define population or populations to be sampled. Exactly what is it you wish to sample? What are your resource problems; are they time sequenced? In most cases you will find it necessary to analyze general information and specific population attributes that will provide the data needed to answer the managers and specialists concerns. Specialists, we found, tend to ask for a great deal more information than what is actually required to make informed resource decisions.

Design of the needed output forms should be considered next. You must design the output forms, and come to agreement among the various resources as to what forms will be developed, how they will be formated, what data elements to include, and how you will use the information. We called this a DRD (Detailed Requirements Definition) i.e., for Resource Inventories (Pulford, el al) in BLM. It was one step in the process of design and automation. We had approximately 20 people working full time for two years and 200 field people advising us on needs for the resource activities. The end result was, that we knew each information requirement, we coordinated forms and we eliminated duplication and overlap. We also came to agreement on data definitions. Until one goes through this process, effective coordination will not happen.

The data elements were key in the above process. After BLM went through the "conflict resolution" on outputs, we defined all of the data elements for each resource activity. If there was disagreement, we tried to resolve it. If it couldn't be resolved we made a management decision that one was right. From this process we developed a data element dictionary. I brought a sample of the dictionary with me in case anyone is interested.

The dictionary is the result of a great deal of work and it is a prime example of standardization and coordination among resources. Each activity knows what others want and need in the inventory process; and they in turn know what the activities will be collecting in their own inventories. In this instance we have an integrated system of inventories based on a logical design and much hard work.

One other point on data elements. You must also agree on the degree of accuracy desired for each item. Quite frankly, we haven't been able to do this. However, I think we can, if we will spend the time and effort to do it. This is closely tied in with the inventory procedures development for each activity and we must have this coordination at this stage if the inventory is to be effective. In other words, each resource activity must have a method to measure each parameter needed to furnish the required data elements.

Creation of a common sampling frame is the next step. The frame consists of the mapped units within the inventory unit. The mapped units in BLM's inventory technique are called Site Write-Up Areas (SWA) and are based on vegetation, soils, and landform. In coordinating resource activities, the mapped units must be useful and meaningful to the majority of the activities. It is difficult at best, and impossible in some situations.

The SWA's were developed primarily for an inventory technique called Soil-Vegetation Inventory method (SVIM) which is the Bureau's basic inventory technique (BLM 1979). The Bureau is working on integrating other resource activities into this inventory procedure. As we viewed the problem of integrating resource activities we started from the DRD effort and used our planning process as the central point to determine what data are needed. Not all areas or resource activities needed to sample at the same level of intensity, nor probably at the same time.

The system, when fully developed, will provide a basic multi-resource inventory, and other resources would sample additional attibutes as necessary. The sampling frame should be capable of launching single-purpose, and multi-purpose and intense inventories where necessary (Lund, 1978). So it is critical to correctly select your mapping units and your sample frame.

The BLM is now working on inventory techniques. That is the work of my former Division - Resource Inventory Systems (RIS). The inventory techniques of the various resource activities are uneven. The Forestry activity has a very comprehensive set of inventory procedures. Other activities do not. This does not mean you cannot coordinate the inventory procedures, though. You can coordinate them through the Data Element Dictionary and an information needs assessment. This kind of work has been done. The procedures then must be developed on DRD data base, taking into account other activity needs.

My last point on inventory design is to test sampling techniques for precision, accuracy and cost effectiveness. And then when you are satisfied in this area, analyze your: (Aldrich, 1977)

(1) Summary Tables and Reports

(2) Models or Predictive Equations

(3) Graphic displays of the mapped, measured and predicted values.

The benefits in designing and coordinating an inventory as outlined are as follows: (Lund, 1978)

1. Combining data collection efforts may reduce field time and overall inventory costs.

2. The integrated effort will create a common sampling frame data base.

3. Standardization of terminology, units of measure, and quality of inventories will increase.

4. An accurate valuation of all involved resources expressed in equal terms may be provided for proper land use decisions.

5. Data can be collected at the same time allowing easier comparisons.

6. Multi-resource inventory may be quicker to conduct than separate inventories.

Problems with any inventory design include:

1. Identifying the minimum data that needs to be collected.

2. Defining the inventory unit, and sampling frame.

3. Having limited information on population and/or cost factors to examine adequately design possibilities and alternatives.

4. Setting high precision requirements on easily obtainable data which could place entire emphasis on only a few variables. In forestry, for example, precision requirements are often set on volume. Other items such as age distribution may be equally important in the management planning.

MULTI-PURPOSE INVENTORIES

I would like to turn now to BLM's actual experience of planning a multi-purpose inventory on-the-ground. I think you will find it enlightening, especially the use of the Bureau's comprehensive planning system to determine the scope of problem areas, and data to be collected, before starting the inventory.

The inventory preplanning process in BLM is linked directly with our planning system. It involves public participation and the scoping of issues which the public and resource managers deem appropriate. It requires detailed information about the resources and data to be collected, and close coordination and cooperation between resource activities.

The BLM preplanning analysis is intended as a guide for use by district offices in all planning. The analysis establishes data requirements, work month requirements and time frames. It assures that the end product is completed at a predetermined level of detail and sufficient quality to meet Bureau standards. The preplanning analysis does more than just start the inventory process. However, it is critical as it sets the stage for the multi-purpose inventory. It includes:

1. Identification of critical land use and resource management issues and problems. To do this all data sources are surveyed to determine major issues and problems in the area. The analysis is to the depth necessary to reveal the type of data and inventory that will have to be available to resolve problems - no more.

At the same time the major issues, problems or critical management situations by activity i.e., range, wildlife, watershed, etc. are identified. These issues and problems are or will be related to the level of detail and data needs. In other words, will the information available or collected for each activity be sufficient to analyze the problems and issues in detail.

2. The second step is to identify data required to meet management needs and strategies. The process requires the input data to be fully comprehensive enough and at a level of detail sufficient to analyze resource values and the magnitude of the issues and problems. It must also meet the level necessary to generate and analyze alternatives so as to provide rational decisions.

Although Steps 1 and 2 are similar there are subtle differences that should be recognized. The first step is based on individual activity needs: but it requires direct coordination among the activities. The second step also requires coordination, however, it reflects multiple-use concerns and therefore requires as much or more coordination among activities than the first step.

3. The third step is to identify the proper intensity of inventory. In BLM a resource management area may be 1,000,000 acres in size and there is usually no need to conduct inventories at the same intensity over the entire area.

Detailed data on all public land resources, as well as socio-economic factors, are required for planning purposes and must come from inventories. There are situations at the other end of the spectrum where public land commodity and amenity values are small and no significant issues or problems will be identified.

Resource use levels may be relatively low and uncomplicated, and there may be little, if any, public controversy. In such a situation a much less sophisticated inventory is required. Data inputs need not be elaborate or detailed. The level of inventory will be scaled accordingly. Generally, if the determination of inventory need has been identified as being of priority, at least one of the resources will require detailed analysis.

The proper level of detail for a specific plan is therefore primarily a function of:

1. Quantifiable and nonquantifiable natural resource values, conditions, and trends.

2. Identified issues and problems.

3. The intensity, types, and patterns of public land uses.

4. The intensity of public concern for NRL management.

5. Land ownership patterns.

Baded on the critical land use and management issues and the level of detail needed, the following are considered in the inventory process:

1. Complexity of probable issues.

2. Data availability.

3. Trends affecting resources in the area.

4. Specific data needs for each activity compared with existing activity data. We do not collect data that is not needed. We tailor the planning processes and inventory needs to the types of decisions that will have to be made.

5. The requirements for additional data:

a. Are there untaped sources of information - other agencies, universities, corporations, organizations, or other segments of the public?

b. Will additional inventory have to be funded, and can it be done internally or by contract?

6. The work months required for data acquisition. We then use a data/analysis and data on-time-frame deadlines such as ES completion dates to set up work schedules for the inventory process. To do this we:

a. Identify actions (inventories) which must be planned in sequence.

b. Identify actions (inventories) which can be done with a partial overlap in steps.

c. Identify action (inventories) which can be initiated simultaneously.

The Soil-Vegetation Inventory Method (SVIM) is the Bureau of Land Management's method for conducting soil and vegetation inventories. The procedure provides a uniform, systematic method for inventorying soil and vegetation resources and collecting data.

The method <u>does</u> <u>not</u> preclude site specific studies (for special purposes), other approved inventories (various forest inventories, forage surveys, etc.) or more detailed inventories (although they can be based upon it). Although SVIM does not inventory <u>all</u> renewable resources, it provided a sampling frame for wildlife species occurrence inventories and gathers basic data used by other resources (recreation, watershed, etc.). It is a multi-purpose inventory system in that other renewable resource inventories are based upon, or directly related to, its procedures. To gather more detailed data, it may be necessary to conduct intensive studies on specific areas of concern. Continuous studies are also essential to monitor changes in base inventory data for necessary adjustments in management as resource conditions change.

The last step is an inventory plan, based on guidance from the preplanning analysis, developed prior to conducting the inventory. An interdisciplinary team is appointed by our District Managers to develop the inventory plan. Based on data needs identified in the preplanning analysis, a team of resource specialists determine the extent and intensity of the inventory. An outline for the inventory plan is as follows:

1. Purpose.

2. Objectives.

3. Description of inventory area.

4. Information required based on issues.

5. Inventory design.

6. Personnel and funding requirement and/or constraints.

7. Logistics.

8. Field measurements and procedures.

9. Compilation procedures.

10. Reporting (progress and results) requirements.

11. Approval process.

12. Files maintenance.

Progress Reviews - The inventory plan sets forth when and how progress reviews will be conducted. The District Manager must appoint a progress review team consisting of resource specialists from the District staff, with assistance from State or other BLM office specialists if desired. Reviews consist of assuring adequate quality and quantity of inventory progress and resolving any problems.

SUMMARY

If the above steps are taken it is my belief that we can achieve standardization coordination and cooperation between resource activities. The job is not an easy one, but this approach is cost effective and in the long run, much more logical in multiuse resource management.

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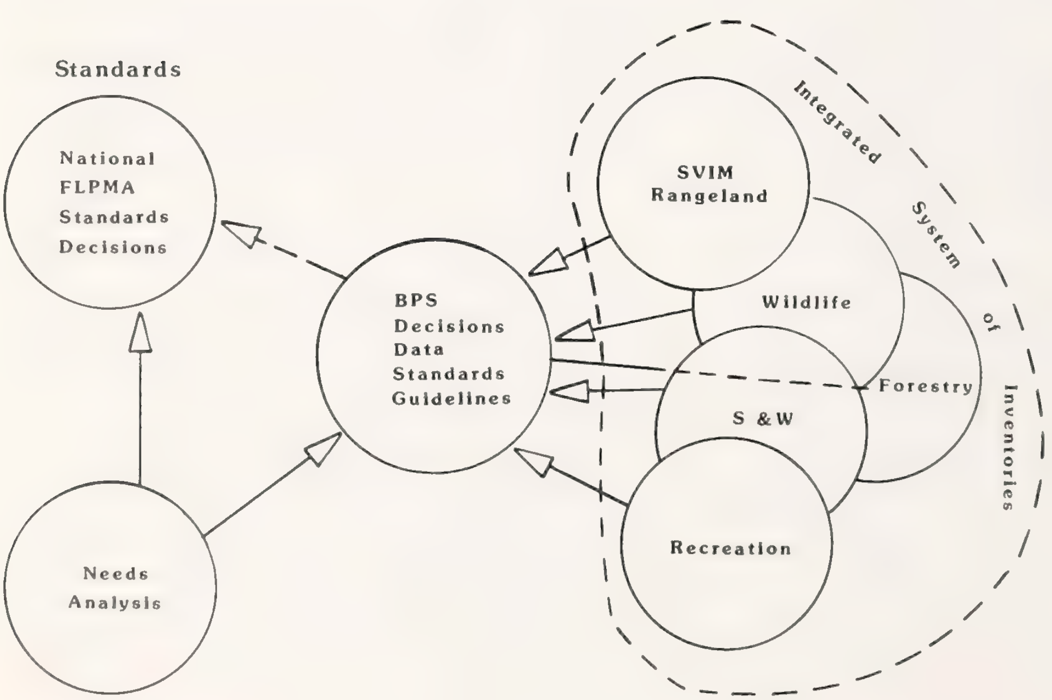
RESUMEN

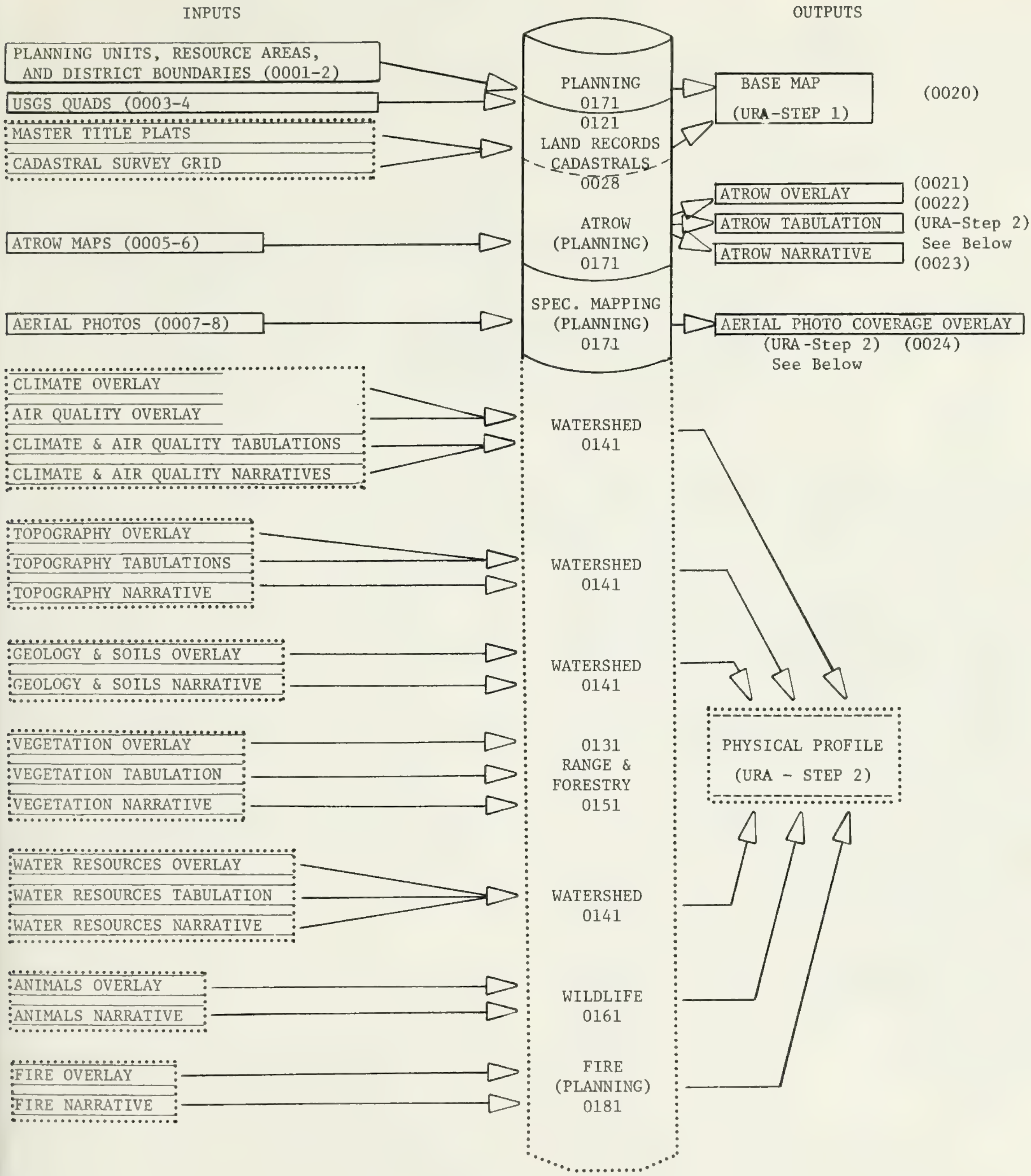
La coordinación y cooperación entre las agencias de recursos requieren un diseño y planificación del inventario que sea completo y que se haya probado debidamente. En particular, un buen diseño de inventario requiere conocimientos sobre la utilización de la data, los objetivos del inventario, los elementos de la data, definiciones, uniformidad de términos, características de la población y muchos otros detalles. En el proceso de diseño, los especialistas en recursos naturales deben estar dispuestos a trabajar unidos para lograr soluciones comunes.

DIAGRAM - PROPOSAL

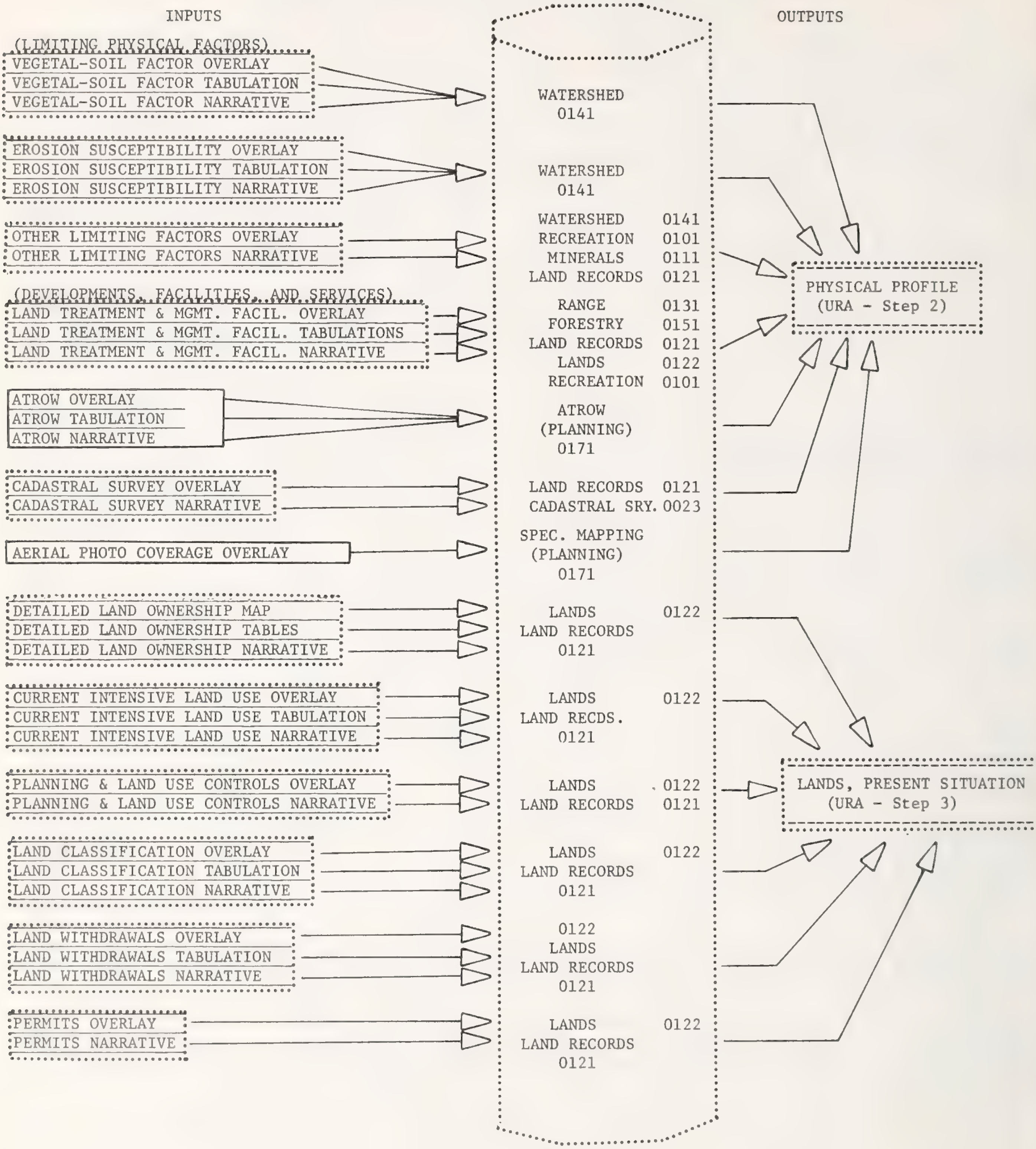
INTEGRATED SYSTEM OF INVENTORIES



PLANNING INFORMATION FLOW DIAGRAM (SYS#0171)



PLANNING INFORMATION FLOW DIAGRAM, CONTINUED - p.2



Standardization, Coordination, and Cooperation Among Resource Agencies[1]

Dwane D. Van Hooser[2]
Alan W. Green[3]

Abstract.--Standardization, coordination, and cooperation between land management agencies is essential if the inventory process is to provide the necessary results for an effective analysis and evaluation of regional or national resource situations. National policy necessary to provide overall direction to the Federal resource agencies in the United States is presented. An approach taken by an inventory unit in the western United States is outlined and the results of two cooperative efforts--one Federal and one State--are discussed.

BACKGROUND

In the early 1970's, the United States Congress began to recognize the need to provide natural resource agencies with some sort of long-term budgeting system that would allow for continuity in planning natural resource programs.

The first piece of legislation specifically dealing with this problem was the Forest and Rangeland Renewable Resources Planning Act of 1974, or RPA (U.S. Laws, Statutes, etc. 1974). The provisions of this act called for a renewable resource assessment, based on a comprehensive survey and analysis of the present and prospective condition of and requirements for, the renewable resources of the forest and rangelands of the United States. In addition, the act directed the Secretary of Agriculture to "develop and maintain, on a continuing basis, a comprehensive and appropriately detailed inventory of all National Forest System lands and renewable resources."

[1]Paper presented at the Arid Land Resource Inventories Workshop, La Paz, Mexico, November 30-December 6, 1980.

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The law also stipulated that the Secretary develop a recommended renewable resource program that "may include alternatives and shall provide in appropriate detail for protection, management, and development of National Forest System, including forest development roads and trails; for cooperative Forest Service programs; and for research." In addition, as part of the program, the Secretary was also directed to "develop and maintain appropriate land and resource plans for units of the National Forest System, coordinated with the land and resource management planning processes of State and local governments and other Federal agencies." If coordinated planning is a legislative requirement, it would seem to follow that coordinated inventories would be a necessity.

The RPA, in its original form, was a landmark piece of legislation. The Congress, however, was not quite finished. In 1976, the National Forest Management Act (U.S. Laws, Statutes, etc 1976) was passed. The law substantially amended the RPA. It provided more specific guidelines with regard to resource inventories. For example, as amended, the RPA clearly directs that the unit plans mentioned above be based on inventories of applicable resources. Moreover, the guidelines for developing the planning regulations specifically provide for obtaining inventory data on the various renewable resources.

The direction provided by this legislation, with regard to inventory, is quite plain and quite comprehensive. The scope of the Forest Survey was expanded to include the renewable resources on all the forest and rangelands of the United States. National Forest System (NFS) was directed to begin an in-depth planning process based on inventory data. The planning process would not present any immediate problems since NFS had sole control over

all National Forests. The expanded scope of Forest Survey, however, began to cause problems as soon as the law was signed. The plain problem was--who is going to do what, where?

Part of the problem developed because another agency in the Department of Agriculture--the Soil Conservation Service (SCS)--had been given the responsibility for conducting forage and soil surveys. This overlap immediately became an area of conflict. A task force was formed to deal with the problems. Among other actions it established guidelines for conducting inventories[4]; the Forest Service would conduct timber inventories on all lands and the SCS would conduct forage inventories on non-Federal lands. These sideboards were agreed to by the respective agency heads and all seemed to be well in the USDA.

Except, the SCS had legislation pending--the Soil and Water Resources Conservation Act or RCA (U.S. Laws, Statutes, etc 1977)--that directed the Secretary to carry out a continuing appraisal of the soil, water, and related resources of the Nation. And, the appraisal was to utilize data collected under this act. Data collection certainly means inventory, and the scope of the inventory was broad.

Congress, however, recognized that there would be overlap in both pieces of legislation. To solve this problem, each act directed that the Secretary use information and data available from other Federal, State, and private organizations and avoid duplicating resource assessments and program planning efforts of other Federal agencies.

In theory, this direction should have solved any emerging problems. In practice, the direction resulted in another task force being organized to deal with authorities, definitions, standards, and inventory methods.[5] A thorough review of the legislated authorities indicated that each agency had been given specific direction and while some overlap did exist, it could be accommodated administratively. The inventory methods used by each agency were sample based and, with proper planning, would be compatible. For the most part, common terms carried common definitions. There was, however, one major exception, the definition of forest land. The Forest Service used 10 percent tree stocking as a minimum criterion for forest land, while the SCS used 25 percent crown cover.

[4]Memorandum of Agreement for Coordination of Range Programs of Nonfederal Forest Lands and Inventory of Forests and Rangelands between USDA Forest Service and Soil Conservation Service, June 23, 1976.

[5]Memorandum of Agreement for Inventory, Appraisal, and Assessment Responsibilities between USDA Forest Service and Soil Conservation Service, January 17, 1977.

On the surface, these differences did not appear to be great, but, when one was equated to the other, the dissimilarity was significant. For example, an analysis of forest inventory data showed that on the average, 25 percent crown cover is, equal to about 65 percent stocking and, similarly, 10 percent stocking is equal to about 4 percent crown cover.

Summaries developed by each agency, using their respective definitions, resulted in estimates of forest land area that differed by 50 million acres (USDA Forest Service 1980; U.S. Dep. Agric. 1980). And, as would be expected, the largest differences occurred in western States having vast areas of rangeland where the transition between forest and range is often not easy to identify. At present, these differences are being reconciled.

This whole exercise brought into sharper focus the fact that intra-agency and intradiscipline inventories are things of the past and that only through close cooperation and coordination can interagency and interdisciplinary inventories be effectively accomplished. To this end, the five major agencies with inventory responsibility in the United States have entered into an Interagency Agreement[6] and formed a high level coordinating committee to address and resolve inventory related problems, such as the definition of terms and methodology.

INVENTORY RESPONSIBILITIES AND APPROACH

These problems of inventory coordination, cooperation, and standardization, which recently have been receiving so much national attention, have long been of concern to Resources Evaluation field units, especially those in the western United States.

The Resources Evaluation Research Work Unit (RE) at the Intermountain Forest and Range Experiment Station (INT), for example, is responsible for inventorying and/or reporting on the resource situation of some 470 million acres of forest and rangeland in the Intermountain and Rocky Mountain States. Data for public lands come from Federal agencies, including Regions 1, 2, 3, and 4 of the National Forest System; nine Bureau of Land Management (BLM) State offices; the BLM Denver Service Center; the Bureau of Indian Affairs and various Indian tribes; and other land management agencies. In addition to the Federal agencies, RE must also coordinate its inventory activities with nine State forestry organizations.

[6]Interagency Agreement Related to Classifications and Inventories of Natural Resources between USDA Forest Service and Soil Conservation Service and USDI Bureau of Land Management, Fish and Wildlife Service, and Geological Survey, June 6, 1978.

In the early 1950's, the coordination problems were virtually nonexistent because RE simply inventoried all lands, regardless of ownership. This was done principally because inventory data in a form usable for resource assessments were not readily available from other agencies. Also, at the time, it was easier to take the information with RE crews than to rely on others to provide adequate data in a timely fashion.

As workloads increased and expertise evolved, however, RE could no longer operate "in a vacuum." The inventory policy with regard to Federal lands was modified. Now these lands are only inventoried by RE crews if data are not available from the responsible agency and if the agency has no plans for inventorying its resources. RE does not, however, inventory National Forest lands.

After many discussions with State and Federal agencies, it was concluded that to get consistent information from cooperators, it was incumbent upon RE to provide leadership and assistance in designing inventories and data processing.

Data processing was a fairly simple matter since most Forest Service Regions were using the FINSYS (Barnard 1978) system and RE was already doing the data processing for many State inventories. The area of inventory design was a different matter entirely. Especially, when the inventories were to include all renewable resources, and provide the capability to monitor changes in the future.

Inventory Continuity

Plan For Regional and State Level Analysis

As a first step, to facilitate obtaining the information from other agencies, an operational plan was developed that outlines the data requirements for producing an analysis of the resource situation within a given geographic area. The main purpose of the plan was to establish a standardized data set that could be addressed by various resource agencies in their inventory activities. The plan also specifies such items as diameter class limits and merchantability standards. In addition, the elements defined provided for a core of information that could be used in making regional and local, as well as National, analyses of the resource situation. Moreover, this core of information also facilitates (a) the identification of stand treatment opportunities, (b) resource output projections, under various treatments, and (c) estimating treatment costs and expected yields.

To date the plan has served two very useful purposes. First, in completing the standardized data set, cooperating agencies ask questions about specific data elements. These discussions provide the opportunity for RE to make certain that what goes into the data set is consistent among agencies and geographical regions. For example, during a recent compilation of inventory data, an inquiry was made with regard to the treatment of cull material. Subsequent discussions revealed that a cull proportion was being assigned to every tree tallied, which precluded any analysis of the cull component of the stand. As a result of the discussion, it was possible to modify the cull factor development procedures so that individual cull trees could be identified.

The second advantage the plan provides is that it serves as a vehicle for discussing basic inventory concepts and design; an area that was in a dynamic state long before the RPA was enacted.

Regional Sampling Network

To allow for a consistent approach to sampling, a decision was made by RE to establish a regionwide network that would provide a standard sampling frame (Resources Evaluation 1978) to aid in the integration of data from various sources and to provide a common base for sampling and future remeasurement. The network consists of a series of points established at 1,000 meter intervals on USGS 7-1/2 minute quadrangle maps. Each map point is identified by Universal Transverse Mercator coordinates and classified in terms of the characteristics that can be obtained from the map itself. Some of these items include slope, elevation, aspect, and distance from a road. Where possible, collateral data, such as soils, annual precipitation, and unique zones, were also recorded. Ownership, one of the major variables used for stratification, is also assigned to each point. Once complete, the network will provide a mechanism for sampling and for monitoring changes in land and resource use.

A big advantage of this map grid is that characteristics of the land at the grid point that do not change or that change very slowly will not have to be remeasured or reclassified during the next inventory. Such things as slope, aspect, and elevation, for instance, should not be expected to change during the inventory cycle. Changes in ownership or land use will be detected during the succeeding inventory.

Nontimber Vegetation

After the plan and the grid establishment procedures were developed, the problem of measuring nontimber resources had to be addressed. For the most part, vegetation on unproductive forest land, or woodland is not easily measured or described. Woodland species generally do not exhibit a central stem tendency, nor do they conform nicely to mathematical relationships.

Procedures have been developed for sampling and measuring the vegetation occurring on these woodlands (Resources Evaluation 1980). Procedures for computing volume were developed on the Carson National Forest in New Mexico (Clendenen 1979) and are currently being modified and calibrated for use in Nevada.

Techniques for measuring other nontimber resources are being developed, patterned after those currently being used in the Southeastern United States (McClure 1979).

EXAMPLES OF HOW IT CAN WORK

Recently, RE had occasion to effectively use data processing capabilities, the sample grid, and the results of some woodland research in a coordinated inventory effort with the Bureau of Land Management in Nevada. Some background information is in order at this point.

A Federal Example

About the time the RPA was being debated, another debate was taking place in Washington D.C. The Natural Resource Defense Council (NRDC) and other associations concerned with natural resource use brought suit against the Secretary of the Interior, Rogers C. B. Morton.[7]

The plaintiffs contended grazing can have a significant impact on the lands and other resources to warrant preparation of detailed environmental impact statements. The Nation Environmental Policy Act (NEPA) (U.S. Laws, Statutes, etc. 1970) states, "major Federal actions significantly affecting the quality of the human environment" shall be accompanied by a detailed environmental impact statement. What the plaintiffs were seeking was a judgment against any further issuance of grazing authorizations until BLM prepared and circulated for public review and comment an adequate impact statement for each district or planning unit where grazing occurred.

Meanwhile, independent of that action, a BLM team of range and other experts was preparing a programmatic environmental impact statement on grazing. That statement, known formally as the Final Environmental Impact Statement on Livestock Grazing on National Resource Lands, discussed the management of livestock grazing through the application of grazing systems and the environmental aspects of this grazing management. It covered all National resource lands in the U.S.

In opposing the lawsuit, the BLM position was that the programmatic statement was adequate and would serve as a foundation for subsequent analyses and statements that might be required for local areas where livestock grazing might have significant negative environmental impacts.

On December 30, 1974, however, the Court held that this programmatic statement alone was not sufficient to comply with NEPA and that livestock grazing represented enough of an impact on the environment to require environmental impact statements on local geographic areas. The Court gave BLM and the plaintiffs 30 days to prepare a timetable agreement for completing these impact statements.

On June 18, 1975, Judge Thomas Flannery signed the two-party agreement calling for impact statements on 212 specific geographic groups of grazing allotments to be completed over the next 13 years. They will cover about 150 million acres of rangeland used for grazing. The environmental impact statements will discuss in detail the environmental effects of livestock grazing activities and "all reasonable alternatives" to those activities.

In Nevada, the agreement meant that BLM would prepare a total of 18 impact statements on about 48 million acres of rangeland. The first Nevada impact statement covering 3.8 million acres was scheduled for completion in 1977. Statements on another 27 million acres are to be finished by September 1981 and on the remaining 17 million by 1988.

To discuss "all reasonable alternatives" in the Nevada environmental impact statements, BLM had to determine the amount and extent of the pinyon-juniper (P-J) resource. Because State BLM personnel were aware of RE recent P-J effort in New Mexico, they requested consultation on possible approaches to obtaining the desired information. As a first step, BLM decided to use the RE sampling grid to select the field locations and RE's P-J measurement procedures for obtaining volume estimates for one district in eastern Nevada. RE agreed to provide the necessary technical assistance to insure the mensurational integrity of the data and to produce the initial volume summaries.

The results of the first year's work were very positive and the decision was made to extend the effort throughout the State. With the support of the BLM Nevada State Office and the Nevada Division of Forestry, a document was prepared that outlined the process for developing the data base needed for assessing the total forest resource situation in Nevada. The document also provides a foundation for cooperation between the Federal and State agencies.

This spirit of cooperation and attendant benefits were recognized by the BLM's national headquarters and considerable support was generated for the inventory, both in terms of dollars and manpower allocation. For example, the initial field effort was conducted out of the Ely BLM district office and covered about 500,000 acres with only a single two-person crew collecting data. The next year, the field effort was expanded to cover slightly more than 1.3 million acres. During the 1980 field season, BLM crews collected data in the Ely, Battle Mountain, Elko, and Carson City districts and a crew from RE provided consistency checking across the State. Nearly 2.6 million acres of P-J were inventoried during the summer of 1980. If the fieldwork progresses as scheduled, the woodland

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[7]Natural Resources Defense Council, Inc. et al., v. Rogers C. B. Morton, Civil Action No. 1983-73. December 30, 1974.

portion of the Nevada inventory should be completed next year (1981)--2 years ahead of the original schedule.

The information collected through this cooperative effort will certainly be of value to BLM in producing the required environmental impact statements. But, in addition, the data on P-J in Nevada will allow RE to produce more current resource summaries for upcoming National assessments and to produce an evaluation of Nevada's woodland resources nearly 5 years ahead of schedule. This is especially significant in light of recent trends in the increasing consumption of P-J for energy.

Overall, this Forest Service/BLM effort has produced much more fruitful results than either agency could have produced alone, and each agency now has a better understanding of the other's mission and responsibilities.

One additional benefit of the Nevada P-J work was that the inventory process for woodlands became more visible to other potential users. The BLM office in Utah has asked for assistance in planning a P-J inventory, and the procedures are going to be used by the USDA Forest Service in the southwestern United States.

A State Example

Another example of cooperation between two agencies that produced excellent results is the recently completed Forest Survey of Montana. Had RE conducted the inventory without outside assistance, only the data necessary to report Statewide resource statistics would have been collected. The State Division of Forestry, however, was interested in producing estimates that would be reliable enough to allow a more comprehensive analysis of multicounty groups for use in State planning. In order to intensify the basic field sample, they were willing to contribute a substantial amount of manpower to the field data collection phase of the job.

To make the analysis of the resource situation more complete and more useful for management planning on State lands, the State requested that some additional information be collected on each field plot. Included were: habitat type, for getting better estimates of site productivity in terms of wood production and wildlife habitat; fuel load, for fire hazard, management, and protection plans; woodland range condition, for estimating grazing potential; wildlife use, for strengthening information on wildlife habitat; and silvicultural treatment potential, to strengthen estimates of opportunities for increasing timber and nontimber outputs from the resource.

Collecting this information did not take a significant amount of additional time, but it did add an extra dimension to the analysis. For example, in the identification of silvicultural treatment opportunities, dichotomous keys were used to classify forest stands into categories of similar conditions. The classification describes a set of circumstances that indicate certain broad treatments would be needed to increase commercial wood production. This kind of information provides an opportunity to make assessments of future wood supply potential as well as to evaluate current stand conditions.

As with the Nevada P-J inventory, the results of the Montana effort have been very positive. Additional data collected--both the intensification and the additional data items--have provided a solid foundation for an in-depth analysis of the forest resources of the State. The total result will be a more effective plan for the management of the resource.

CONCLUSIONS

RE's work with cooperators has revealed several things. First, coordination and cooperation are generally possible and desirable where mutual needs exist for resource information. Second, the standardized procedures that result have great benefit now and will have in the future when reinventories are made. And, third, the essential ingredient to effective cooperation is clear and continual communication with other agencies and their local offices. It is only with such communication that opportunities for cooperation in resource reinventories can be identified.

With increasing needs for better resource data for National, regional, and local planning, the agencies responsible for those resources must act in concert to meet the demands of the public. Coordination and cooperation of inventory efforts is not only desirable, it is essential. Moreover, not to take advantage of such opportunities is economic nonsense.

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RESUMEN

La uniformidad, coordinación y cooperación entre las agencias de manejo de tierras es esencial si el proceso de inventario ha de proveer los resultados necesarios para el análisis y la evaluación efectiva de las situaciones de recursos regionales o nacionales. Se presenta aquí la doctrina nacional necesaria para proveer una dirección general a las agencias federales de recursos en los Estados Unidos. Se bosqueja en este artículo la dirección que tomó una unidad de inventario de la parte oeste de los E.U., y se exponen los resultados de dos esfuerzos cooperativos- uno federal y uno estatal.

Seccion III. Confrontando el Reto de Inventarios de Tierras Aridas — Una Panorámica[1]

Section III Meeting the Inventory Challenges of Arid Lands — An Overview[1]

Ing. José M. De la Puente E.[2]

INTRODUCCION

Hemos escuchado con interés - a través de la excelente presentación que han hecho quienes nos antecedieron en el uso - de la palabra - lo que son las zonas áridas, su caracterización ecológica, el uso de que se las ha hecho objeto y sobre todo, los retos que se presentan a la inventiva humana en el propósito de lograr la cuantificación de sus recursos.

El planteamiento de las alternativas de solucion a la problemática expuesta, - se obtendrá mediante la participación de un selecto grupo de ponentes, quienes presentarán los resultados de numerosas experiencias logradas a través de arduas jornadas de trabajo y estudio, que aportan - valiosos conocimientos sobre la metodología a emplearse en el levantamiento de -- los inventarios forestales en zonas áridas del mundo.

La presentación de los temas a cargo de esta Sección Tercera, permitirá que, - además de la naturaleza técnica de los trabajos, conozcamos sus áreas de influencia, las instituciones que los auspiciaron y - los autores que los realizaron, lo cual - fomentará el intercambio personal y de experiencias, entre quienes concurrimos a esta Reunión Internacional.

Vale la pena mencionar, que en la - Sección Tercera se encuentra el mayor número de ponencias de todo este evento que nos convoca, lo que demuestra que muchos investigadores alrededor del mundo, están aceptando el reto de ofrecer soluciones a los problemas de inventarización de los - recursos naturales de las zonas menos privilegiadas de este planeta.

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[1]Trabajo presentado en la Reunión Internacional Sobre Inventarios de Zonas -- Aridas, La Paz, B.C.S., México.

[2]Director General del Inventario Nacional Forestal, México.

OBJETIVOS

Los objetivos que se pretenden lograr en esta Sección de trabajo son los siguientes:

- Presentar las últimas experiencias para llevar a cabo la cuantificación di-- recta y la representación cartográfica, - de los recursos naturales de zonas áridas.

- Proporcionar información que apropicie el manejo integrado de tales recursos.

- Coayudar al mejor aprovechamiento de la vegetación natural y, consecuente-- mente, al mejoramiento del nivel de vida de los habitantes que pueblan las zonas - áridas del mundo.

ESTRUCTURA DE LA SECCION III

Atendiendo a la naturaleza de las -- múltiples actividades que conforman los - inventarios forestales, se juzgó pertinente organizar nuestra Sección Tercera, en seis mesas de trabajo, con temas afines - entre sí, y denominadas como sigue:

Mesa A - Planificación de Inventarios
Mesa B - Esquemas de Clasificación
Mesa C - Percepción Remota y Carto-- grafía
Mesa D - Métodos de Muestreo
Mesa E - Técnicas para Mediciones de Campo
Mesa F - Sistemas de Análisis de Datos

En virtud de que los inventarios forestales, particularmente los de zonas -- áridas, tienen un papel relevante en el - adecuado manejo de los recursos naturales, durante el desarrollo de este evento - según decíamos - se presentará un crecido - número de estudios sobre el particular. - Esto nos ha impuesto la necesidad de celebrar dos mesas de trabajo simultáneamen-- te.

Con el objeto de orientarnos, según nuestros particulares intereses e inclinaciones, es conveniente recordar que el día de mañana, por la mañana, se desarrollarán al mismo tiempo los temas de Planeación de Inventarios y de Esquemas de Clasificación, mientras que por la tarde del mismo día y el jueves por la mañana, se presentará el de Percepción Remota junto con el de Métodos de Muestreo.

Asimismo, ese día por la tarde, se discutirán los temas de Técnicas para Mediciones de Campo y de Sistemas de Análisis de Datos.

BREVE RESEÑA DEL TEMARIO

El éxito de la inventarización de recursos forestales, se obtiene mediante la adecuada coordinación de las múltiples actividades que su ejecución demanda. Y, precisamente, cada una de las mesas de trabajo abordará las que son indispensables y relevantes.

Planeación de Inventarios

Sabemos, por ejemplo, que la planificación constituye la parte fundamental de cualquiera empresa, situación que no es ajena a los inventarios forestales, debido a que - entre otras ventajas - permite establecer la secuencia de las etapas por desarrollar, lo que redunda generalmente, en la efectividad de las operaciones y en el abatimiento de los costos.

La creciente necesidad de aumentar la eficiencia en los inventarios forestales, ha promovido un notable desarrollo en materia de técnicas de planificación. De esta forma, se aplican procedimientos que van desde simples gráficas, hasta el cálculo matemático, cuyo proceso requiere frecuentemente de la computación electrónica.

Hay que tener presente que la planificación implica, por una parte, el determinar con precisión qué datos son realmente necesarios, excluyendo los detalles cuya utilización práctica se dificulta y, por la otra, el seleccionar la metodología que proporcione la información deseada con el mínimo de inversión, tiempo y esfuerzo. Ambas consideraciones han de examinarse ampliamente en las ponencias que se presentarán el día de mañana en las que además, se discutirán modelos específicos de planeación, como el que presenta Felger para inventar ciertas especies del Desierto Sonorense, que son verdaderos cultivos en potencia; o el denominado R.O.S., presentado por Brown, Driver y Berry relativo a la inventarización de valores recreativos de las zonas áridas.

Para observar el avance tecnológico y científico de los procedimientos empleados en la planeación, tendremos la oportunidad de conocer los trabajos realizados por Boris sobre el empleo de modelos matemáticos para determinar la asignación óptima de tiempos, en la ejecución de inventarios forestales; también, los sistemas estadísticos utilizados por Nichols para definir el diseño adecuado de muestreo y el tamaño óptimo de la muestra.

También habrán de señalarse las particularidades de los trabajos de planeación llevados a cabo en regiones específicas, como los inventarios de ecosistemas del norte de México, de Medina, Vazques y Gutierrez, o los métodos y costos de programas canadienses, que presentará Welch.

Esquemas de Clasificación

La ecología de las zonas áridas del mundo comprende una gran variedad de componentes, cuyo manejo adecuado, exige el conocimiento de sus características. Esta situación provoca que aún falte mucho por conocer de tales regiones, pudiendo establecerse que los esquemas adecuados de clasificación representan un papel importante, al promover la armonía de las relaciones entre el hombre y la naturaleza.

Numerosas instituciones y personas físicas, se interesan en contar con información básica de las zonas áridas. En algunos casos los datos no existen, o cuando los hay, a menudo se encuentran dispersos y respaldados por criterios disímbolos entre sí. Por ello, se adjudica particular importancia a los métodos o esquemas de clasificación y, estamos seguros que con las aportaciones que se presenten en esta mesa, se podrán disipar muchas dudas al respecto.

La vegetación constituye un elemento básico de los citados componentes ecológicos, y en virtud de que la forman variadas especies botánicas de muy diversos hábitos de crecimiento, la mayoría de las ponencias que se presentarán en esta apartado, se refieren a las experiencias que se han tenido en la agrupación de las comunidades vegetales, de acuerdo a sus características.

De esta manera, tendremos la oportunidad de conocer los trabajos que Maldonado y Zavala han efectuado en México para clasificar, el primero, la vegetación de las zonas áridas del norte, y el segundo, la comprendida en el Valle de Tahuacán, -

al sur de nuestro país, así como los estudios que Ellatifi llevó a cabo en las zonas áridas de Marruecos.

Como muestra el avance tecnológico en la materia, McDaniel y Haas por una parte y Rohde y Johnson por la otra, presentarán sus experiencias en la clasificaación y caracterización de los recursos naturales, mediante procedimientos electrónicos usando imágenes Landsat; mientras que Brown, Johnson y Moran, disertarán sobre el uso de sistemas digitalizados para inventarios de aguas superficiales, factor muy importante para el manejo de zonas áridas.

Merkel nos hablará de un sistema de clasificación de suelos, vegetación, agua y relieve, en tanto que Dixon presentará sus valiosas experiencias sobre evaluación de condiciones hidrobiológicas.

Percepción Remota y Cartografía

La elaboración de mapas representativos, constituye uno de los principales medios para normar el aprovechamiento y conservación de los recursos naturales, no sólo de las zonas áridas, sino de cualquiera región cuyas características se pretendan conocer.

Ya que mediante la cartografía han de representarse gráficamente, tanto la configuración de la superficie de la tierra como las diferentes condiciones de los recursos por estudiar, se requiere que el grado de precisión de este tipo de trabajos, se fije de acuerdo a las especificaciones determinadas previamente. Como ejemplo de la aplicación de estas técnicas, Panzer y Rhody nos informarán sobre los resultados que obtuvieron al representar gráficamente a la vegetación, mediante el empleo de fotografías aéreas de gran escala.

El inicio de programas ERTS en el año de 1972, promovió el auge en las técnicas cartográficas, al posibilitar la observación de los recursos de la tierra desde el espacio exterior, lo que ha facilitado considerablemente el estudio tanto de la situación actual de dichos recursos, como la de los factores externos que inciden en su desarrollo.

En la actualidad, estas técnicas tienen grados distintos de aplicación, que van desde la simple identificación de caracteres en las imágenes de satélite, hasta la utilización de imágenes digitalizadas cuyo análisis se logra a través de sistemas de cómputo electrónico.

Entre las ponencias que se presentarán para ilustrar estos aspectos, tenemos la de Hutchinson, donde se muestra la utilización de imágenes Landsat para el estudio integrado de las regiones áridas de California y la de Bonner que utilizó el mismo tipo de imágenes para llevar a cabo inventarios de manejo en el noroeste de Arizona. Asimismo, Lozano y Martines disertarán sobre la elaboración de planos de uso del suelo a partir de las multicitadas imágenes, en una región del oriente de México, y Robinove presentará la forma de detectar los cambios en la productividad de las zonas áridas, utilizando imágenes Landsat tomadas para un mismo lugar en dos épocas distintas.

Para establecer con mayor claridad el empleo combinado de imágenes de satélite y fotografías aéreas, McLeod y Johnson discutirán la manera de estimar la presencia de biomasa en California, mediante imágenes Landsat y fotos aéreas de gran escala; mientras que Moval y Johnson explicarán cómo se captan datos para apoyar decisiones de manejo de vegetación, a partir de las propias imágenes Landsat, fotografías aéreas a color e información de campo.

En la misma mesa de trabajo, Amidon presentará una técnica matemática adaptable tanto a minicomputadoras como a otros métodos de colección de datos, para detectar los errores que se cometen al emplear imágenes de satélite en la representación de características forestales. Linden y Rohde comentarán sobre seis técnicas para utilizar imágenes Landsat en el estudio de tipos de vegetación de zonas áridas; tales técnicas describen desde la aplicación de sistemas sencillos como la fotointerpretación directa de las imágenes, hasta el uso de computadoras para el análisis de información digitalizada.

Sistemas de Muestreo

Puesto que ninguno de los recursos naturales de las zonas áridas, por sí solo, resuelve el problema económico de sus habitantes, es imperativo que las técnicas que se apliquen para determinar su magnitud y establecer su manejo, resulten económicas.

Como sabemos, uno de los procedimientos para lograr este objetivo, lo constituye el muestreo de áreas representativas. Durante el desarrollo de este subtema, se describirán técnicas con cuya aplicación se producen resultados similares a los que se obtendrían mediante el reconocimiento de la totalidad de los recursos, con

la ventaja adicional de ahorrar tiempo y reducir substancialmente las fuentes de error.

Las experiencias en la aplicación de procedimientos económicos de muestreo, son amplias y de muy diversa naturaleza, por lo que las ponencias que integran este subtema comprenden una gran variedad de tópicos, difíciles de comentar en esta ocasión, por las limitaciones del tiempo. Baste decir que se discutirán temas que tratan desde la determinación del comportamiento y distribución de fauna silvestre a partir del análisis fecal, hasta la aplicación de mecanismos especiales para la inventarización de zonas erosionadas, usando imágenes de satélite.

Técnicas para Mediciones de Campo

Respecto al subtema de Técnicas para Mediciones de Campo, podemos señalar que su importancia estriba en que frecuentemente no se presta la atención debida a las maneras de obtener los datos numéricos del material de estudio, lo que redunda en imprecisiones de origen.

Paradójicamente, la información así lograda muchas veces se procesa mediante sofisticados programas de computación electrónica.

Si la captación de datos es una de las fases más costosas en un inventario de recursos, debemos de subrayar la importancia de llevar al cabo, estrictamente el número y tipo de mediciones determinadas previamente, en la fase de planificación.

Como en el caso del subtema anterior, en éste se incluyó un numeroso grupo de estudios, cuyo contenido sería prolijo analizar. Por lo tanto, únicamente señalaré que tendremos aportaciones encaminadas al estudio de comunidades vegetales ubicadas en zonas áridas de los estados de Puebla y de Baja California, aquí en México, así como en los estados de Utah, Oregon y Nuevo México en los EE.UU. Además de sendos trabajos sobre asociaciones vegetales en Kenya, y en el estado de Monagas en Venezuela.

Todos estos estudios presentan experiencias para la determinación de volúmenes, espesura, composición florística y otras características de la vegetación natural. Pero también tendremos ponencias sobre la cuantificación de superficies acuáticas, de fauna silvestre y de salinidad de los suelos.

Sistemas de Análisis de Datos

En la actualidad, la forma común de procesar datos numéricos es a través de computadoras electrónicas que realizan, en poco tiempo, grandes cantidades de operaciones matemáticas.

Resalta, entonces, la importancia de conocer las características de los sistemas empleados en el procesamiento de los datos captados durante la ejecución de inventarios de recursos de zonas áridas.

Sobre el particular, habrá la oportunidad de conocer lo que para problemas confrontados en México, han realizado: Varela, en escala nacional; Ruiz, Oliva y Ham, para el noroeste, y Rasmussen, Folliot y Halffter para reservas de la biósfera en Durango.

Respecto a zonas áridas de los Estados Undios, se discutirán los trabajos de Gedney sobre algunas formas de actualizar inventarios, y los de Gregoire y Barrett sobre la aplicación de modelos de regresión. Asímismo, se presentarán las conferencias de Moser Jr. y Throssell sobre el uso de terminales de transmisión de datos y la de Costello sobre los sistemas de procesamiento empleados en inventarios de pino piñonero y de táscate o enebro.

Adicionalmente, dentro de este subtema, conoceremos las experiencias de Beltz, por una parte, y las de Gryczam por otra, sobre el empleo de registradoras portátiles, y de sistemas de información para el aprovechamiento de recursos naturales, respectivamente.

De la misma manera, podremos escuchar el trabajo de Lanly y Singh, donde se describirá el sistema de procesamiento de datos en inventarios de vegetación tropical.

No quisiera dejar de comentar, finalmente, que el estudio de las zonas áridas constituye una importante aportación al desarrollo de esos lugares donde tantas necesidades existen. Esta consideración reviste singular relevancia para algunas regiones, como mi propio país - México - donde la condición de aridez se extiende sobre 74 millones de hectáreas habitadas por unas diez millones de personas. A ellas y a otros núcleos humanos de las zonas áridas del mundo, es a quienes - en primera y última instancias - deberán estar dirigidos nuestros estudios, nuestros esfuerzos y nuestros logros, en esta importante Reunión Internacional.

SECTION III

MEETING THE INVENTORY CHALLENGES

ON ARID LANDS - AN OVERVIEW

Ing. Jose M. De la Puente E.

We have heard what arid lands are, their ecological characterization, the uses they have been subjected to, and - especially - the challenges that are presented for inventorying their resources.

These challenges are being met by several institutions and persons, whose works are to be presented here, in six panels:

a) Inventory Planning
b) Land Classificacion
c) Remote Sensing and Mapping
d) Sampling Schemes
e) Resource Measuring Techniques
f) Data Analysis Systems

The majority of the papers in this workshop are within the frame and scope of our Section III, therefore, analysis presentations and discussions are likely to be interesting and promising.

It would be highly desirable that our works and conclusions should be directed - in the first place and in the last instance - to the people living in the arid lands, for they are the most important of the renewable natural resources.

PANEL A

Setting Inventory Objectives[1]

Harry V. Wiant, Jr.[2]

Abstract.--Inventory objectives must be set which will provide the data needed by the information-users. The importance of the four w's, what, where, why, and when, in setting objectives is emphasized, and a weighting scheme is described.

The setting of inventory goals is dictated by managers seeking answers to questions important in the decision-making process. In the private sector, the primary goal of management usually will be maximizing profit, and the goals of inventories will be product oriented (e.g., pulpwood and sawtimber volume). In the public sector, goals relate to the maximum satisfaction of the public, and inventory goals may include many non-timber aspects (e.g., wildlife populations, recreation potential).

It has often been said that once a problem is well defined it is half solved. This is certainly true of natural resource inventories. Metcalf (1974) indicated that the clear expression of the objective is the most critical phase in the entire inventory process. Unfortunately, it is often the phase that receives the least attention, and the usefulness of the inventory is thereby diminished. Perhaps it would be helpful for those responsible for setting objectives to remember four w's:

What?
Where?
Why?
When?

What information is desired? What precision is needed for the information items? What are the budgetary limitations? What information is available from previous inventories and surveys? Many foresters have been asked to cruise timber for landowners with no specifications as to the information needed by potential buyers. Is volume by species adequate, or is grade information desirable also? Is number of trees by diameter classes needed? Obviously the answer to these questions will influence the sampling design utilized. The inventory specialist should remember that the most efficient sampling design will select more sampling units in those portions of the population which vary most. If volume information alone is sufficient, unequal probability schemes such as 3P or point sampling, or a combination of the two may be selected. If a stand table is of primary importance, sampling with fixed-area plots may be most efficient. Should growth information be most important, fixed-area plots again may be best as there tends to be more variation in growth of small than of large trees. It is most helpful if the precision desired for information items is specified in statistical terms. Again, decision-makers often fail to provide this information so neatly, often because they are not knowledgeable in that area.

Where is the area involved? Hopefully adequate maps and photographs are available. Poorly defined property lines greatly complicate the work of the inventory specialist. In the eastern United States, for example, fences through woodlands are rarely maintained in these days of high labor cost and absentee ownership. As a result, much time is wasted by those better at cruising than surveying in trying to locate property lines.

Why is the information needed? How will it be used? Much money has been squandered on CFI systems which provided great quantities of expensive detail which were put to no use by decision-makers. There is a natural tendency to conclude in the air-conditioned office that several pieces of

[1]Paper presented at the Arid Land Resource Inventories Workshop, La Paz, Mexico, December 2, 1980

[2]Harry V. Wiant, Jr. is Professor of Forestry, Division of Forestry, West Virginia University, Morgantown, W. Va.

information might be of some use some day, which adds needless expense and complications to an inventory.

When should the inventory be completed? Time is our most precious commodity, and a careful setting of objectives can provide savings down the line. I know of one CFI system for a modest-size forest that was so intensive that each "year's" measurement took three years. Consequently, decision-makers were soon disillusioned, and it was abandoned after two incomplete measurements.

Husch (1971) authored a 121-page publication for FAO entitled, Planning a Forest Inventory. It would be worthwhile reading for anyone facing this task. Three sentences stress the importance of the planning process:

> "Planning a forest inventory involves the consideration of a complex series of problems. On the one hand, it is necessary to decide precisely what information is really needed and to exclude details which cannot be put into practical use under existing or foreseeable conditions. On the other hand, methods must be selected which will yield the desired information with the least expenditure of money, time and effort".

Myers[3] pointed out that an inventory or survey is an information-gathering endeavor and must be designed to answer the questions asked by the information-users. In that context he recommends these steps in a forthcoming book:

[3]Myers, W. Setting objectives and designing the inventory. Talk presented to the Allegheny Section, Society of American Foresters, Pittsburgh, Penn., February 7, 1980.

1. Have the information-users rank their information needs and devise a weighting scheme which is satisfactory to them. For example, for a given inventory situation one might find:

Information need	Relative importance
sawtimber volume	55
cordwood volume	25
deer browse plants	15
potential camp sites	5

2. Plan the most efficient inventory possible to provide the information desired. Obviously, the inventory design will be determined more by the information needs of greater relative importance.

Once goals have been set, then the inventory specialist is faced with the big "H", How to achieve the goals? Many of the following papers will deal with this fascinating topic.

LITERATURE CITED

Husch, B. 1971. Planning a forest inventory. Food and Agri. Organization of the United Nations, FAO Forestry and Forest Products Studies No. 17.

Metcalf, M. E. 1974. Setting objectives for forest resource inventories. In: Inventory design and analysis. Proc. Inventory Working Group, Society of American Foresters, Fort Collins, Colo.

RESUMEN

Los objetivos de un inventario deben ser estipulados de tal manera que provean la data necesaria a los usuarios de esa información. La importancia de las cuatro "W": "what," "where," "why," y "when," en la estipulación de objetivos se enfatiza, y se describe aquí un esquema de ponderación.

How to Determine What You Can Afford to Spend for Inventories[1]

Bertram Husch[2]/

Abstract.--There are two general approaches to deciding on how much to invest in an inventory; "a priori" allocation of funds and allocation based on either a subjective or analytical benefit-cost appraisal. A subjective appraisal is most commonly used. The analytical procedure which can be applied in special cases uses a cost-plus-loss analysis.

INTRODUCTION

The question which I have been asked to address "How to Determine What You Can Afford to Spend on Inventories" is especially vexing and I must advise you from the outset that I know of no clearcut procedure or formula which can be operated under all circumstances to provide a definitive, quantitative answer. Of course, there are elements in trying to answer the question which can be objectively quantified but, in many cases, there are other elements which are subjective in nature and opinions of various persons may differ. It is the effect of these subjective elements which make a simple reply to the question impossible.

Although my personal experience has been mainly in inventorying forest resources, it has become increasingly clear to me that the problems of inventorying forest as well as other natural resources, including those of arid regions have much in common. To be sure, detailed measurement techniques and instruments will vary with the resource under investigation but the basic considerations of planning and costing will be very similar.

With this in mind I would like to present to you some thoughts which I believe should be considered when faced with the problem of deciding on how much can be justifiably spent on an inventory of a natural resource.

1/Paper presented at the International Workshop on Arid Land Inventories: Developing Cost Efficient Methods. IUFRO Forest Resource Inventory Subject Group, La Paz, Mexico. November 30-December 6, 1980.

2/Project Manager, UNDP/FAO Project, Chile, "Forestry Research and Development". Santiago, Chile.

COST FACTORS IN AN INVENTORY

Before discussing the question of how much to spend on an inventory I believe it would be worthwhile to briefly consider those factors which influence its cost. I submit that the main factors are: the type of information required, accuracy (and precision)3/, size of area to be investigated, size of the smallest unit area, the inventory design, and the analysis procedure.

General information about the resources of an area will usually be relatively inexpensive, especially if the data can be obtained from aerial photographs or other remote sensing devices. As more detailed information on the resources become necessary the cost of the inventory increases. This is especially the case as the number of measurements and amount of field work increases.

The degree of accuracy (and precision) of the information required from the inventory greatly influences cost. Obviously, the greater the accuracy (and precision) the greater the cost of obtaining the information to meet the requirement.

The cost per unit area for an inventory of a large zone will be less expensive than that for a limited area. Modern inventory techniques, including the use of photogrammetry, satellite sensors, photo-interpretation, statistical methods and computers require specialized equipment and personnel whose costs will be less per unit area if the total area to be inventoried is large.

3/Accuracy is here defined as the closeness of a measurement or estimate to the true population value. Precision, on the other hand, is the degree of agreement in a series of measurements. In sampling, precision, as expressed by a standard error, refers to the deviation of sample values about their own mean, which, if biased, does not correspond to the true population value.

Another important factor influencing cost is the size of the minimum area for which individual estimates of the natural resources are to be obtained. To illustrate, it may be possible to prepare resource estimates for units of 10,000 hectares to an acceptable standard of accuracy (or precision) for a small expenditure per hectare. On the other hand, if estimates of the same resources are required for each 100 hectare unit within the overall 10,000 hectares to the same standard of accuracy, the cost per hectare (and the total cost) could be 100 times greater.

Clearly, the cost of an inventory will be strongly affected by the design to be used for obtaining the required data. Initially, one might consider a design requiring 100% measurement of the resource under investigation. In the majority of cases such a design is discarded because of prohibitive cost or physical impossibility of execution. Thus a cheaper and more feasible sampling design will be employed. Together with the sampling design chosen, costs will be affected by the equipment, instruments, kind of transport, photography, etc. which must be employed.

The analysis procedure used in processing the measurements will also influence the cost. For example, hand computation will have a different cost than data processing by computer. Further, if computers are used the preparation of new programs or the use of already existing ones will result in different costs.

Although the cost factors have been mentioned separately they are actually interrelated since the total cost of the overall design and execution of an inventory is the net outcome of all the factors taken together.

HOW MUCH TO SPEND ON AN INVENTORY?

Now let us turn to the problem of deciding on how much should be spent on an inventory. In mulling over this question I can detect the dichotomy, shown in figure 1, of how decisions are made on how much to invest in an inventory. Two main procedures are identifiable:

1. "A priori" assignment of funds
2. Assignment of funds based on some form of benefit-cost analysis

"A priori" Assignment of Funds

"A priori" assignment of funds means that decisions are taken on how much to spend on an inventory before establishing the inventory specifications 4/. I would characterize these decisions as being of three types. The first would be the arbitrary allocation of an amount of money with little or no technical basis for the decision. It is difficult to defend such a procedure and has little to recommend it although, unfortunately, it has been used, especially if inventory specialists are not consulted when an organization's budget is being prepared. A second "A Priori" procedure is to allocate an amount of money based on the costs incurred in carrying out similar inventories in the past. This procedure has been widely used since it is simple and has the weight of actual experience to give it appeal. A third approach which has been used is to make a rough guess of the value of the resource to be inventoried and then, arbitrarily, decide on what percent of this value one could feel justified in spending on an inventory. For the three alternatives just mentioned one would have a maximum amount of money available for the inventory. The problem would then be to design an inventory which would provide the maximum amount of the desired information within the cost restriction. One could estimate the precision attainable employing various possible inventory designs. Of course, there always exists the possibility that the amount of money allocated will be insufficient to get the information desired or that only an unsatisfactorily low level of precision would be achieveable with any design. If additional funds to improve the situation cannot be obtained there is always the alternative of simply cancelling the inventory and not spending money which would provide unsatisfactory results.

Benefit-Cost Considerations

The other branch of the dichotomy, shown in figure 1, can be called assignment of funds based on benefit-cost considerations. A natural resource inventory can then be considered as a production process consisting of two stages:

1. The design and physical execution in the field and office of an inventory and its resulting cost (the input).
2. The output of the inventory or the information that is generated, the way it is used and its value.

Mensurationists and specialists in inventory work have dedicated great effort to the first stage, i.e., devising better designs and measurement techniques, but much less to evaluating the usefulness of the information produced in relation to the cost of obtaining it.

Under a benefit-cost approach estimations would be made of the costs which would be incurred in obtaining varying amounts of information at different precision levels. The amount finally allocated for an inventory would then be the result of weighing these costs against the usefulness and risk of errors in decisions based on the information and deciding upon some appropriate expenditure. The decision on the amount would be the result of a cyclic process in which inventory specifications

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4/Specifications mean descriptions of the kinds of information, with their allowable errors and probabilities, that the inventory is expected to provide.

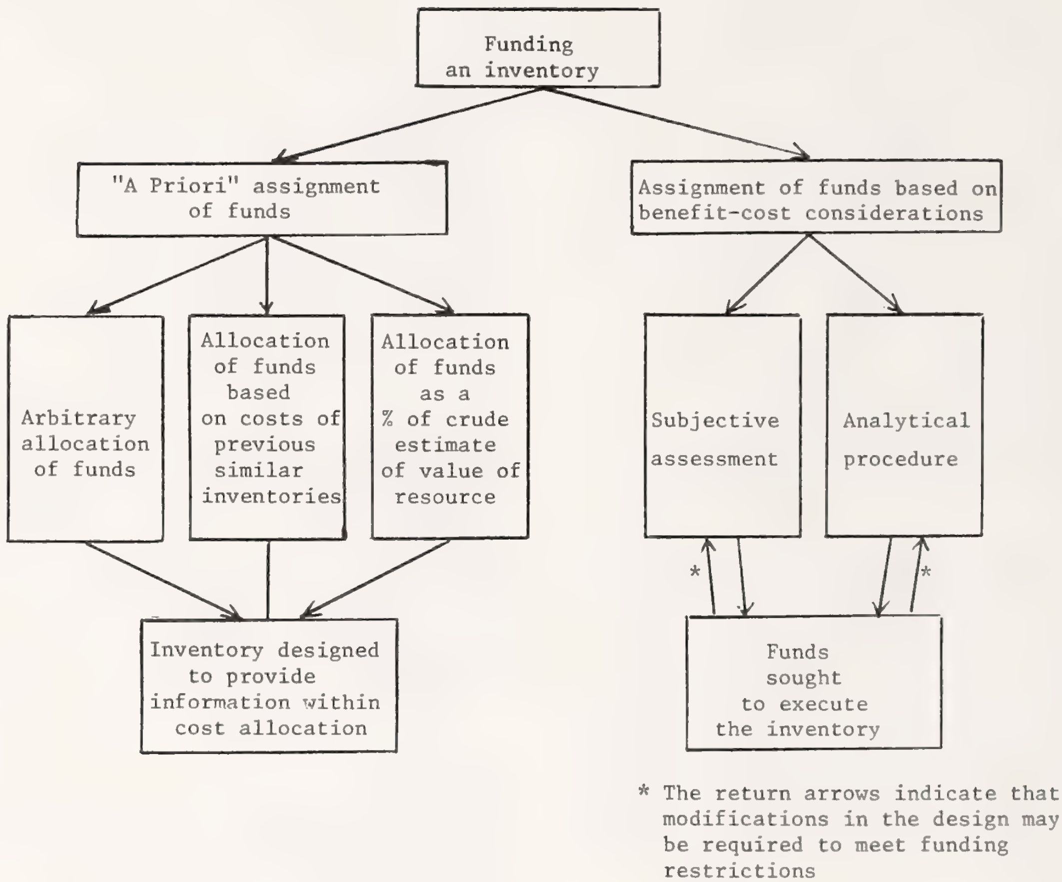

Figure 1.--Generalized Processes for Deciding on How Much to Spend on an Inventory.

and design may be iteratively modified until some acceptable cost level is reached.

The limitation in using a benefit-cost analysis in inventory work is that in many cases it is difficult or impossible to evaluate the benefits since many of the values of the information are not quantifiable. Further, as in most endeavours, inventories are affected by diminishing returns. In other words, increases in the amount and precision of information from an inventory will eventually reach a point where the value or usefulness of the information will not increase. There is little doubt that this statement is true but the difficulty is to quantify it so that it can be used to decide on what investment is appropriate.

This benefit-cost approach has two applications which I have distinguished as subjective and analytical. The subjective application means that one sets the specifications for an inventory based on judgement (often based upon past inventories or those done by others), including its level of precision, and then tries to prepare the most practical and efficient design, costs it, and then seeks the necessary funding. The analytical application, in contrast, determines the sample size and precision considering the quantitative effects of decisions based on the information provided by the inventory.

Let us start by considering the subjective benefit-cost application. Here the inventory designer will decide on the required information and precision level and then prepare a sampling design and cost. Although there is no explicit analysis of benefits it is implicit in the choice of inventory specifications. If much information and high precision are required it means more intensive sampling and, consequently, higher costs. Less detailed information and lower precision levels, on the other hand, result in lower

inventory costs. Decisions on the amount or kind of information required from an inventory are straightforward since it is relatively easy to visualize how the information will be used. It is more difficult to decide on what precision level to use. Since the precision level is the amount of error one is willing to tolerate in the estimates, the most logical way to decide on it would be to assess what effect error will have on the way the information is used. Thus, one might ask; what would happen if the estimates were not correct to ± 1%, 5%, 10%, etc? If one were to actually employ such a procedure we would be in the other type of benefit-cost analysis, i.e., analytical. But in most natural resource inventory work this has not been applied or possible and precision levels employed have been those traditionally used or employed in other, similar inventories. Little attention has been paid to the question or to the development of methodologies to determine quantitatively how much error can be tolerated in the decisions based on the inventory information. The difficulty in attacking this problem is the lack of quantitative expressions of the consequences of errors of different sizes as they affect decisions based on inventory results.

Since the output values (the information) from an inventory are difficult to express in monetary terms the choice of alternative levels of precision, with their costs, are most often subjective modifications of a benefit-cost analysis. In other words, it is conceptually simple to estimate the costs for obtaining a given amount of information at a specified level of precision. However, to decide which precision level is the best choice is essentially an opinion.

The analytical type of benefit-cost analysis which has found some application in inventory work uses the least-cost-plus-loss procedure. This procedure has been employed in various investigations to decide on how much to spend on wildfire protection (See Davis, 1965 and references given) but few attempts have been made to apply it in forest mensuration or inventory work. The basis of such a procedure is shown in figure 2. The forms of the several curves shown are simply illustrative and may vary in detail although the trends are correct. The graph shows that the cost of inventory will rise as the amount of information and/or precision increases. The loss curve shows that the loss in value of the information or losses due to decisions based on it will decrease as the amount of information and/or precision increases.

The cost-plus-loss curve is the sum of the values from the two previously mentioned curves. The optimum level of expenditure for an inventory would be the minimum point on the cost-plus-loss curve.

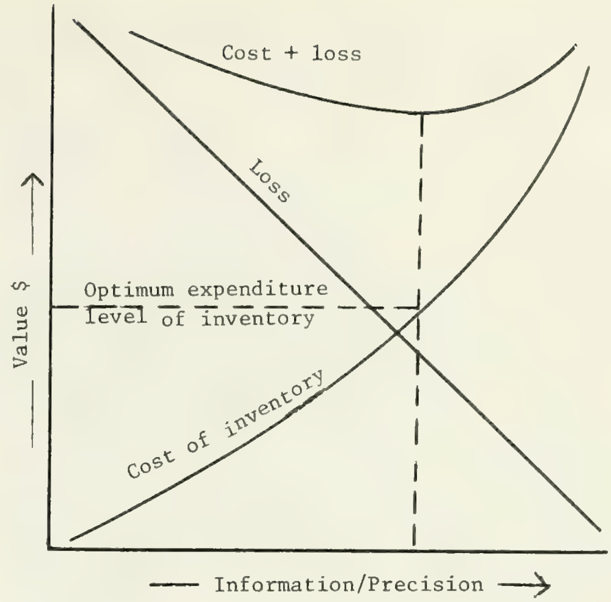

Figure 2.-- Example of determination of optimum expenditure level for inventory based on cost-plus-loss function.

This procedure is described by Cochran (1977) and has been used by Blythe (1945) in determining sample size in log scaling and by Hamilton (1978, 1979) in forest inventory.

Employing this procedure, instead of first choosing a precision level and then determining the sample size, the procedure is reversed. A sample size is determined for a given sampling design, from a cost-plus-loss function. The precision level can then be estimated for the sample size or from the results of executing the inventory. In sum, the procedure determines sample size by evaluating the trade-off between the costs required to attain increasing precision (larger sample size) and the value or need for the additional precision. Hamilton (1979) has summarized this cost-plus-loss analysis in inventory as consisting of the following steps:

1. Development of a cost function which includes costs of sampling, data processing and any other costs incurred in obtaining inventory information.
2. Development of a loss function which describes the losses that occur when decisions are based on inventory estimates which are different from the true population values.
3. Evaluation of the statistical distribution of the possible results of the inventory.

Finally, using the cost-plus-loss function one estimates the sample size required. Thus, the precision level is determined after deciding on the optimal sample size.

The main difficulty in applying this procedure is developing the loss function. For most inventory planning situations it will be difficult to quantify the impact that errors in information will have on decisions and the decision maker. This is especially the case in dealing with large-scale regional or national inventories of natural resources. It is even more difficult if one is concerned with natural resources for which market values are non-existent or difficult to assess. The procedure is most applicable for intensive inventories of limited areas where it is possible to place specific monetary values on the resource being investigated. Hamilton (1979) has applied the procedure to the special case of a timber sale inventory where it is possible to assign a value to the loss resulting from differences between the true and estimated quantities of the resource.

CONCLUSIONS

The summary given here of how inventory costs are decided upon substantiates my earlier statement that there is no standarized, universal procedure for deciding on how much to spend on an inventory. Decisions could be reached using an analytical benefit-cost-approach if we had ways of quantifying the benefits or losses which would result from inventory information at varying precision levels. I would hope that more attention is given to the problem in future research.

Given the present state of knowledge, I would recommend that one first considers the cost-plus-loss procedure and use it if is possible to develop a loss function. Under the more usual circumstances, this may not be possible and the subjective benefit-cost procedure would be the next best alternative. To the extent it is possible to quantify the effects of different levels of precision on the usefulness and benefits to be derived from the information this procedure verges on the analytical. If such quantification is impossible one must fall back on the choice of precision levels which have proven satisfactory on other similar or related inventories.

Less desirable are the "A Priori" methods for deciding on how much to spend on an inventory. Of these methods, the use of cost figures from previous inventories is a satisfactory way,providing the physical conditions of the resource are similar and one is satisfied to use the same inventory specifications. In the absence of cost information from other inventories, the allocation of an amount equivalent to a proportion of a rough estimate of the value of the resource can offer a reasonable basis for deciding on the expenditure. Finally, the least defensible basis for deciding on how much to spend on an inventory is the arbitrary allocation of an amount without previous technical considerations.

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RESUMEN

Para decidir cuánto tiempo dedicar a un inventario se pueden utilizar dos enfoques generales: la distribución "a priori" de fondos, y la distribución basada en un estimado subjetivo o analítico del costo-beneficio. El estimado subjetivo se utiliza más comúnmente. El procedimiento analítico que es aplicable en casos especiales, utiliza el análisis de costo-más-pérdida.

Optimal Allocation of Time in Resource Inventories[1]

Boris Zeide[2]

Abstract.--According to a rather realistic model, plot size and time allocation between travel and plot measurement have actually no bearing on cruise efficiency.

INTRODUCTION

Time required for resource inventories is usually spent on (1) measurement of sample plots, and (2) travel between the plots. In a cruise reported by Mesavage and Grosenbaugh (1956) plot-measurement time was 2.2 times greater than travel time, while in a resource inventory of woodland in Paraguay this ratio was 8 (Taaffe 1979). The question arises whether there is an optimal allocation of time spent for measurement and time spent for travel, an allocation which would minimize total time while maintaining the same desired accuracy. In my recently published article (Zeide 1980) a simple positive solution was suggested: measurement time should be equal to travel time.

This solution hinges on two assumptions: (1) The coefficient of variation among plots of a certain size P is proportional to the plot size raised to the $-\frac{1}{4}$ power; (2) plot-measurement time is proportional to the plot size raised to the 3/4 power. As I have found lately, both assumptions have a restricted applicability. In some cases they work well. I tested the first assumption which was empirically discovered by Freese (1961) using data provided by Prodan (1968), and found an excellent confirmation: the power was -0.249. A similar estimate (-0.27) was found by Taaffe (1979) from a resource inventory of wildland in Paraguay. However, Loetsch et al. (1973) indicated that this assumption holds only for forests with a specific degree of heterogeneity. Now, after a field test of the assumption, I am inclined to agree with the latter opinion. Last summer my students layed out 200 x 100m^2 plot in primeval beech-hemlock forest (Tionesta Research Natural Area, Allegheny National Forest, Pennsylvania). All trees higher than 1.3m were measured and mapped. The coefficients of variation among subplots of different sizes are shown in table 1.

Table 1.--Coefficient of variation of basal area as a function of plot size in a primeval forest

Number of plots	Plot size, m^2	Coefficient of variation
200	100	49.9
100	200	35.8
50	400	27.7
18	1111	16.7
8	2500	14.2
4	5000	8.1

Here the power is -0.438. It differs substantially from Freese's approximation and is close to randomly distributed population (where the power is -0.5).

Wiant and Yandle (1980) in response to my article (1980) pointed out a limited applicability of the second assumption. They accepted the power equal to 1 instead of 3/4 based on data provided by Avery and Newton (1965).

OBJECTIVE

Given a desired accuracy find a general form of the relation between travel and measurement time which minimizes total time.

MODEL

Assumptions

To provide a general solution we shall not specify the certain powers in the relations discussed above. Instead let us assume that (1) the coefficient of variation, C, among plots of size P is proportional to the plot size raised to some positive power g:

$$C = hP^{-g} \quad [1]$$

[1]Paper presented at the Arid Land Resource Inventories Workshop (La Paz, Mexico, November 30-December 6, 1980).

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where h = coefficient of proportionality.
(2) Plot-measurement time, m, is proportional to the plot size raised to the power c:

$$m = bP^c \quad . \qquad [2]$$

Total Time

Total time, T, required to measure n plots of size P to obtain desired accuracy E can be written as follows:

$$T = n(t + m), \qquad [3]$$

where t = travel time per plot.

To facilitate the calculation of the extreme values let us present total time as a function of a single variable, plot size.

It is known that

$$n = \left(\frac{Ct}{E}\right)^2 , \qquad [4]$$

where t = appropriate value of Student's t-statistic.

Using equation [1] we can write:

$$n = \frac{h^2t^2}{E^2}P^{-2g} = kP^{-2g} \qquad [5]$$

where $k = \left(\frac{ht}{E}\right)^2$.

Travel time between two plots, t, is proportional to the distance, D, between the plots and inversely proportional to travel speed, s:

$$t = \frac{D}{s} \quad . \qquad [6]$$

From elementary geometric consideration the distance can be presented as a function of total area, A, and number of plots, n:

$$D = \left(\frac{A}{n}\right)^{\frac{1}{2}} \qquad [7]$$

Thus from equations [5],[6], and[7] travel time will be:

$$t = aP^g \quad , \qquad [8]$$

where $a = \left(\frac{A}{k}\right)^{\frac{1}{2}} \cdot \frac{1}{s}$

Finally from equations [2], [3], [5], and [8] total time can be presented as follows:

$$T = kP^{-2g}(aP^g + bP^c) \quad . \qquad [9]$$

Optimal Plot Size

Now we can find optimal plot size P* (which corresponds to the minimum of total time) from:

$$T' = 0 \text{ and } T'' > 0. \qquad [10]$$

This size is:

$$P^* = \left[\frac{ag}{b(c - 2g)}\right]^{\frac{1}{c-g}} . \qquad [11]$$

Optimal plot size can be expressed in terms of an arbitrary chosen plot size P. From equations [8] and [2]

$$a = tP^{-g} \qquad [12]$$

and

$$b = mP^{-c} \qquad [13]$$

Therefore

$$P^* = P\left[\frac{t}{m} \cdot \frac{g}{c - 2g}\right]^{\frac{1}{c-g}} . \qquad [14]$$

Optimal Allocation of Time

According to [8] and [2] we can present optimal travel time as:

$$t^* = aP^{*g} \qquad [15]$$

and optimal measurement time as:

$$m^* = bP^{*c}. \qquad [16]$$

The ratio between them gives us optimal allocation of time for travel and measurement:

$$\frac{t^*}{m^*} = \frac{a}{bP^{*c-g}} \quad . \qquad [17]$$

At the same time, from equations [12] and [13] we can write:

$$\frac{a}{b} = \frac{tP^{c-g}}{m} \quad . \qquad [18]$$

Therefore

$$\frac{t^*}{m^*} = \frac{t}{m} \cdot \left(\frac{P}{P^*}\right)^{c-g} \quad . \qquad [19]$$

According to equation [14]:

$$\left(\frac{P}{P^*}\right)^{c-g} = \frac{m}{t} \cdot \frac{c - 2g}{g} \quad . \qquad [20]$$

Hence

$$\frac{t^*}{m^*} = \frac{c - 2g}{g} \quad . \qquad [21]$$

DISCUSSION

Thus we have obtained a simple formula which describes an optimal ratio between travel and measurement time. This formula is a generalization of the particular solution discussed previously (Zeide 1980). One can arrive at this solution by substitution of c = 0.75 and g = 0.25 into equation [21].

The coefficients c and g can be found for a given forest during preliminary work. Coefficient g reflects the relation between the coefficient of variation and plot size. Coefficient c relates measurement time and plot size. There is hardly any relation between the coefficients, for one of them (g) reflects biological phenomenon while another (c) is a function of a surveyor's skill.

Coefficient g can vary at least from 0.25 (Freese 1961, Prodan 1968) to 0.44. The range of coefficient c even in a small sample is 0.69 - 1.10 (Mesavage and Grosenbaugh 1956, Avery and Newton 1965). In both cases the range is approximately equal to the lower value. Coefficient c is roughly twice as large as g. At the same time equation [21] calls for the calculation of c - 2g. Therefore, one can expect that this difference and as a result the ratio will be close to zero and highly variable even for a particular forest. As for different locales the ratio varies from

$$\frac{0.69 - 0.88}{0.44} = -0.4$$

to

$$\frac{1.10 - 0.50}{0.25} = 2.4 \; .$$

when we deal with five cited observations.

Even barring meaningless negative values the range of the ratio between travel and measurement time precludes any inference on optimal allocation of time. Thus, the analysis of equation [21] leads to an important practical conclusion which is far from being obvious: according to the presented model, plot size and time allocation between travel and measurement have actually no bearing on cruise efficiency.

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RESUMEN

De acuerdo a un modelo bastante realista, el tamaño de la parcela y el tiempo asignado entre el recorrido y la mensura de la parcela no tienen actualmente relación alguna con la eficiencia de la tasación.

Inventorying the World's Arid Lands for New Crops: A Model from the Sonoran Desert[1]

Richard S. Felger[2], Linda Leigh[2], Stephen L. Buchmann[3], Dennis O. Cornejo[2], Mark A. Dimmitt[4], Donald Johnson Gordon[5], Carlos Nagel[6], Lynn Ratener[2], Charles A. Stigers[2]

Numerous native plants can provide important crops adapted to local conditions. New crops could result in a stable equilibrium between economic and ecological conditions. A three-phase method for selecting promising species is described and results of recent research in the Sonoran Desert are presented to illustrate how the procedure is used. Promising Sonoran Desert plants identified by this approach include diverse life forms such as legume trees and shrubs (e.g., mesquite), ephemerals, columnar cacti, saltgrasses and seagrasses.

INTRODUCTION

Present trends of desertification in the Sonoran Desert region indicate an urgent need for inventorying rapidly diminishing local plant resources and preserving germ plasm from selected arid-adapted plants. Our primary emphasis is on developing locally adapted crops from indigenous species that can be grown with minimal inputs of fresh water and energy, or even saline water.

The methodology involves a natural history, regionally based design for desert agroecosystems. Most of these desert crops are being developed from the repertoire of plants utilized since ancient times by native peoples of the Sonoran Desert region. If adopted, this strategy could result in a substantial increase in agricultural diversity and stability by developing crops to fit the environment rather than changing the environment to fit the crop. The increase of regionally adapted crops should have significant, long range effects on conservation of fresh water and energy, advancing worldwide political and economic stability.

The Sonoran Desert, encompassing 310,000 km^2, supports a flora of 2,500 species of seed plants (Shreve and Wiggins 1964). At least 450 species of this flora were used for food by the local people, and 40 of these species (1.6% of the total flora) served as major wild food resources (Felger and Nabhan 1978; Felger 1979). Such species provide the nucleus for our research. Extrapolated to the world as a whole, this allows a crude estimate of 30,000 species of edible plants, with approximately 3,000 potential major food resource species (ca 1.5% of the total world flora). In contrast, the most important food crops of the world number only several dozen species, and seven of them account for the overwhelming majority of world agriculture: wheat, maize (corn), barley, soybean, common bean, and potato. Also, these are not arid-adapted crops.

This discussion concentrates primarily on methods of inventorying, studying, and developing plant resources for human and livestock food, although multiple uses or by-products are also being considered. We are conducting a detailed inventory of the use of wild plants, as well as some nearly forgotten locally domesticated crops. The research is aimed at adapting the most promising of these plants for modern agriculture. These crops from the Sonoran Desert should be suitable for arid lands in other parts of the world. Furthermore, the concepts and methodology of the resource inventory, investigation, and development can serve as a model for research and development in other climates and for non-food resources such as energy and fiber crops (Hodges et al 1981).

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[1]Paper presented at the Arid Lands Resource Inventories Workshop: La Paz, Mexico, November 30-December 6, 1980.

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METHODS

Our research is divided into three phases, each providing information for selecting promising taxa to be further studied (fig. 1). The phases are: (1) Initial inventory and investigation of potential crops from the Sonoran Desert flora; (2) Initial evaluations, ecological studies, selections and experimentation of target species; and (3) Intensive selection, evaluation, domestication, and adaptation to modern agriculture. In this research system, each species or taxon may be studied at a rate independent of the other species or taxa.

Phase I

The first phase consists largely of comprehensive ethnobotanical investigations and biological evaluations. The emphasis is on wild plants. Our ethnobotanical work involves lengthy interviews, open-ended questions, and observations of actual practices. In this regard, the following information is gathered with the aid of local native consultants:

A. Cultural and dietetic importance of a given plant
B. Phenology of crop and scheduling of harvest
C. Harvest techniques
D. Processing and preparation practices
E. Storage techniques
F. Location of plants or populations with superior qualities
G. Pest losses and natural pathogens
H. Natural history information.

The identities of plants utilized are documented with voucher specimens deposited in public herbaria. Seeds, fruits, tubers or other edible parts are collected for Phase II nutritional analyses, and germ plasm storage and/or propagation. The potential of each taxon for development as a crop is evaluated by the following criteria for potential agronomic significance:

A. Phenological properties such as simultaneous ripening of harvested parts
B. Indehiscent fruit (particularly significant for legumes), or non-shattering inflorescense (e.g., grasses)
C. Other favorable harvest characteristics, such as larger fruits or seeds
D. Drought and salinity tolerance and other desert adaptations
E. Variation across the range of the species distribution
F. Hybridization potential (number of related species or taxa, natural hybrids, etc.).

The weighting of these criteria may differ between taxa and growth forms.

Species or taxa from the Sonoran Desert which form the nucleus of our new crops research are listed in table 1. The potential new crop species being investigated fall into several diverse growth-form categories, each of which requires a somewhat different inventory, experimental, and cultivation practice. These growth forms include desert trees and shrubs, columnar cacti and other succulents, root perennials, ephemerals, perennial grasses, and seagrasses. These plants span the environmental gradients of the Sonoran Desert.

Phase II

Once a promising target species or taxon has been selected, the second phase of research follows. This includes more intensive field observations and sampling, manipulations of natural and cultivated populations, pollination ecology studies, and chemical and nutritional analyses. Initial agronomic assessments are made based on these studies.

Field Observations and Sampling.--Observations and measurements of the target species are made from wild populations for characteristics such as yields of edible parts, primary productivity, growth, morphology and habitat preference. Critical organs or parts such as fruit or seeds are sampled for nutritional analysis.

Collections across as wide an environmental gradient as possible provide information on natural variation and help determine limiting factors which would be important under agricultural conditions. The number of study sites depends on the size of the geographic range and diversity of habitats encountered. Gradients of major importance are precipitation, soil moisture, winter minimum temperatures, and soil salinity. Target species' ranges and collection points will be documented with clear acetate maps overlaying a base map of these physical parameters.

The primary study sites include extremes of the species range within the Sonoran Desert region in order to determine potential limiting factors. If a species displays significant agronomic potential as well as relatively high variation between sites, we increase the number of study sites and establish experimental plantings in order to separate genetic from environmentally induced traits.

Special attention is placed on legumes capable of fixing nitrogen under desert conditions. Rates of nitrogen fixation are calculated using the acetylene-reduction technique (Hardy et al 1968). Also of significance are the effects of abiotic and seasonal factors on rates of fixation and nodulation.

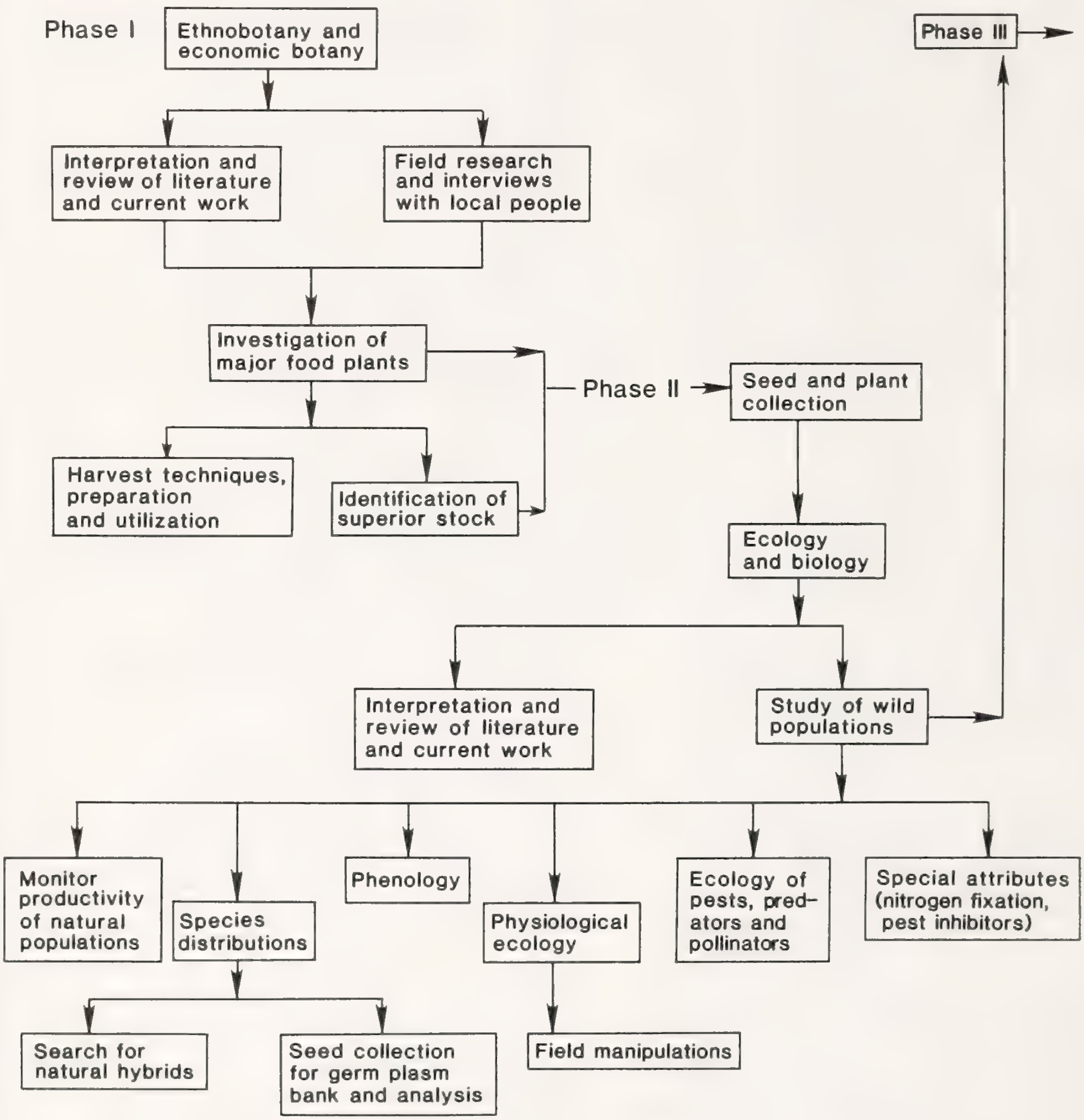

Figure 1. Research methods for developing ecologically-adapted new crops.

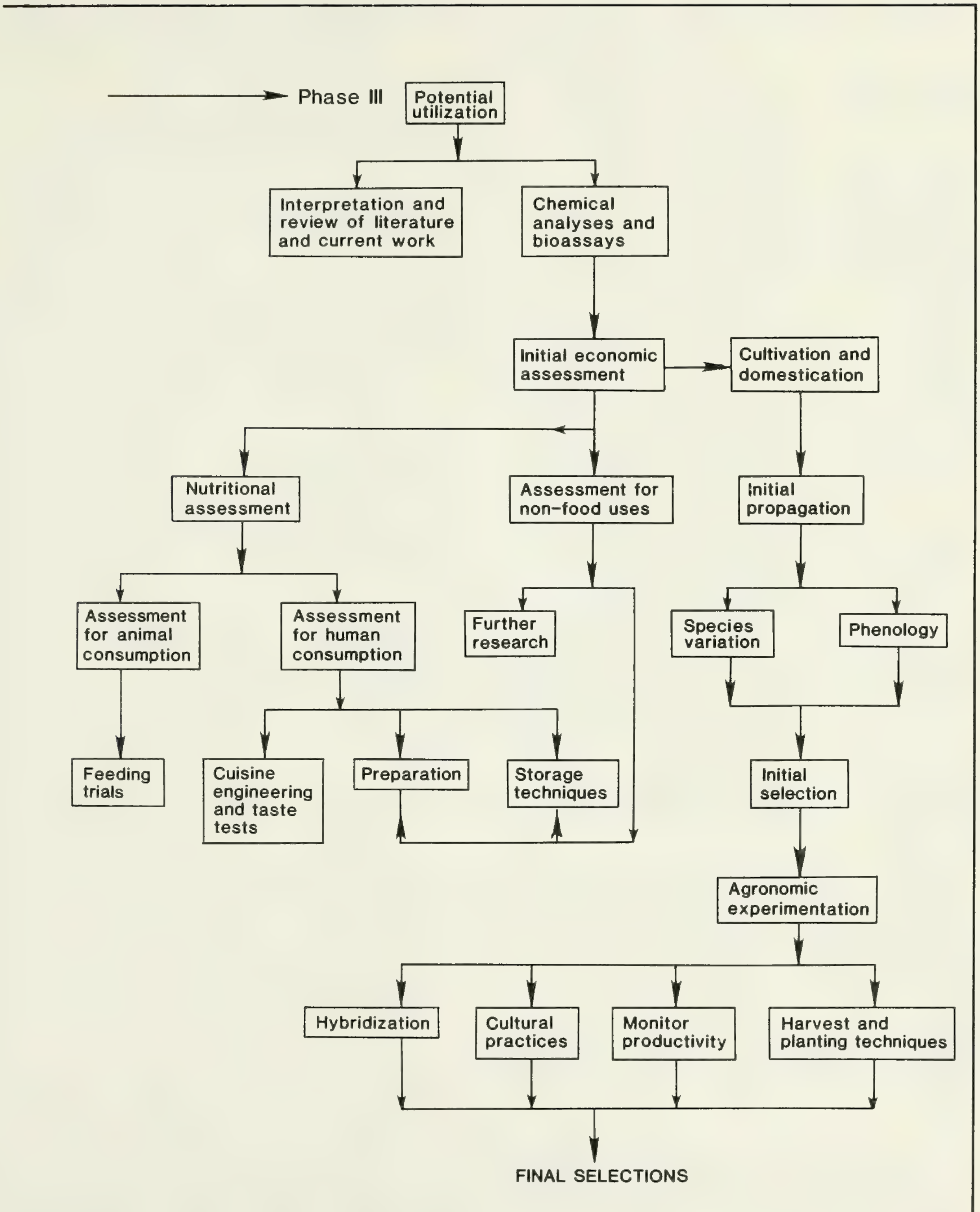
Phase III
Potential utilization
Interpretation and review of literature and current work
Chemical analyses and bioassays
Initial economic assessment
Cultivation and domestication
Nutritional assessment
Assessment for non-food uses
Initial propagation
Assessment for animal consumption
Assessment for human consumption
Further research
Species variation
Phenology
Feeding trials
Cuisine engineering and taste tests
Preparation
Storage techniques
Initial selection
Agronomic experimentation
Hybridization
Cultural practices
Monitor productivity
Harvest and planting techniques
FINAL SELECTIONS

Table 1.--Initial list of potential crop species from the Sonoran Desert.

Growth Form and Species	Common Name	Major Economic Parts	Major Nutritional or Economic Significance*	Present Phase of Research (see Fig. 1)
EPHEMERALS				
hot-weather species:				
Amaranthus spp. (Sonoran species)	careless weed bledo	seed plant	protein (16.2-16.9%), oil (7%) forage	1
Mentzelia spp.	blazing star	seed	protein (19.4-21.4%), oil (34.5-42.4%)	1
Phaseolus acutifolius	tepary	seed plant	protein (21-32%), carbohydrate, forage	3
cool-weather species:				
Descurainia pinnata	tansy mustard	seed	protein (24.4%), oil (38.4%)	1
Lepidium spp.	peppergrass	seed	protein (24-28%), oil (23.5-27.7%)	1
Lesquerella spp.	bladderpod	seed	protein (20-24.4%), oil (20-39%)	1
non-seasonal species:				
Oligomeris linifolia	linear-leaf cambess	seed plant	protein, oil? forage?	1
ROOT PERENNIALS				
Amoreuxia palmatifida	saiya	seed root	protein (11.3%), oil (14%) carbohydrate	2
Cnidoscolus maculatus	mala mujer	seed	oil (49.8-52%), protein (32.6%)	1
TREES AND SHRUBS				
legumes:				
Acacia cochliacantha	boat-spine acacia	seed wood	protein fuel	1
Cercidium floridum	blue palo verde	seed young stems & leaves	protein (27.5-29.9%) limited forage	2
Cercidium microphyllum	foothill palo verde	seed	protein (25.7-27.5%)	2
Lysiloma divaricata	mauto	seed wood	protein (33.1%), oil (12.9%) fuel	1
L. watsoni	tepeguaje	seed wood	protein fuel	1
Olneya tesota	ironwood	seed heartwood	protein (28.8-33.2%), carbohydrate sculpture	2
Prosopis velutina and spp.	mesquite	mesocarp (fruit) seed wood gum, sap flowers fruit	carbohydrate (protein 5.8-8.1%) protein (32.0-39.9%) fuel medicine & dye honey, pollen livestock feed	2,3
desert palms:				
Brahea armata	blue hesper palm	seed	carbohydrate	1
Washingtonia spp.	desert fan palm	fruit/seed	carbohydrate	1
CACTI				
columnar cacti:				
Pachycereus pecten-aboriginum	echo	fruit pulp seed stems	carbohydrate protein (29.4%), oil (32%) pharmaceuticals	1
Stenocereus gummosus	pitaya agria	fruit	carbohydrate; fresh or dried fruit, wine	1
S. thurberi	organ pipe	fruit	carbohydrate; fresh or dried fruit, wine	1
prickly pears and cholla:				
Opuntia phaeacantha	prickly-pear	fruit pulp	carbohydrate	1
O. fulgida & spp.	cholla	fruit	carbohydrate, protein?	1
SALTGRASS				
Distichlis palmeri	Palmer saltgrass	seed herbage	carbohydrate, protein (9%) forage	3
SEAGRASSES				
Phyllospadix torreyi	surfgrass	seed	carbohydrate, protein (14.0-17.9%)	1
Zostera marina	eelgrass	seed herbage	carbohydrate (50%), protein (13.5%) forage	2

* Nutritional data from: Cruz 1973; Earle and Jones 1966; Felger 1975, 1979; Felger and Nabhan 1976, 1978; Felker 1976, 1979; Gentry and Barclay 1962; Glenn et al 1981; Jones and Earle 1962; Nabhan and Felger 1978; Nabhan et al. 1979; National Academy of Sciences 1975; and unpublished data of Buchmann, Cornejo, Felger and others. For further information on research and development of these plants see Felger and Nabhan (1978) Felger et al (1980), Fontes et al (1981), National Academy of Science (1975), Ritchie (1979).

Field Manipulations.--Field experiments are designed to document yields of the desired plant product and its relationship to environmental parameters. Several treatments will be grown under one or more watering, fertilizing, salinity, or planting (field geometry) regimes. Each experiment will be replicated several times, depending on the design, to facilitate an analysis of variance or a multiple analysis of variance (Little and Hills 1972).

These experiments are conducted on natural populations for large long-lived perennials (e.g., trees and shrubs) using permanent study sites as controls. For smaller, shorter-lived plants such as ephemerals and root perennials, field manipulations are probably best effected under cultivation.

Pollination Ecology.--Most of the potential cultigens on our list are self- incompatible and dependent upon insects for their outcrossing. In arid lands bees are abundant, diverse, and important as pollinators for many plants such as legumes.

Observations on the floral biology of each target species are performed in wild populations, field plots, and/or under greenhouse conditions. Reproductive biology is investigated using bagged inflorescences and hand crosses. Insect visitors in natural areas are collected at frequent intervals over a period of several days. Insects are identified by specialists and deposited in suitable museums as voucher and reference specimens.

Flight cages are erected over selected plants in the wild and under cultivated conditions to document if fruit set is economically enhanced with solitary bees and honey bees. It is then possible to establish the appropriate number of colonies, or solitary bees or domiciles, for efficient fruit/seed set of each crop on a commercial per hectare basis.

Laboratory Chemical and Nutritional Analyses.--Chemical analyses are performed to determine qualitative and quantitative levels of proteins, essential amino acids, desirable carbohydrates, lipids, vitamins, minerals and toxins. These data, coupled with analyses of yields, provide major guidelines to selection and improvement. Although there are numerous reports on nutritional qualities of various Sonoran Desert food plants, there are few samples large enough to be statistically significant. We have begun analysis of large numbers of samples whenever feasible.

Initial Assessment.--Among the important criteria for evaluation of target species are high nutritional value and the potential to attain economically favorable yields. We believe the economic threshold for annual seed/fruit crops is on the order of 2,000 kg/ha. However, our initial goals for certain species are somewhat less than this, since the presumably smaller demands for water, fertilizer, energy, and maintenance should reduce production costs. Selection and refinement of technique should further increase yields. Our present information indicates that many long-lived desert legume trees and shrubs can produce yields of at least 2,000 kg/seeds or pods/ha (Cornejo and Felger in prep.). Important factors for increasing quality and yield in cultivation may include: supplemental water and nutrients; extremes in weather; and existing genetic variability (including nutritional values, insect and disease resistance, and hybridization potential).

Germ Plasm Conservation.--Germ plasm banks are repositories where some of the genetic diversity of both wild and domesticated organisms can be preserved. These play a crucial role as wild species are extirpated by expanding human populations, and the multitude of indigenous strains of crop plants are replaced by newer varieties with less genetic plasticity (see National Research Council 1978). The Arizona-Sonora Desert Museum has important and increasing collections of Sonoran Desert plants and seeds. The germ plasm banks will serve as distribution centers of plant material for other institutions, researchers, and private individuals. Those species which are successfully introduced into general cultivation provide an additional dimension for maintenance of germ plasm diversity.

Phase III

Once a species has been selected from Phase II, intensive cultivation and domestication will begin. Although our research has not progressed to this point, Phase III investigations will include:

Ecological Studies and Manipulations.--Field studies and manipulations will continue on cultivated populations. Studies of pollination ecology and insect pests will be intensified.

Nutritional Analysis.--Tests for specific nutritive components will be far more quantitative than the largely qualitative proximate analyses of Phase II.

Bioassays - Laboratory Animals and Livestock Feeding Trials.--Livestock feeding trials will be conducted to determine digestion efficiencies, metabolic efficiencies, and growth potentials (weight gain per unit time). Some laboratory feeding trials will be conducted by independent laboratories.

Intensive Horticultural and Agronomic Experimentation and Development.--In general, standardized agronomic methods will be applied. Extensive genetic manipulation and selection can take place.

Economic Assessment.--Data from Phases I and II will allow for assessments of detailed agricultural economics

Information Dissemination.--At this stage of work, it will be advantageous to set up a network of

information dissemination at a popular as well as technical level in a bilingual format.

Culinary Trials.--The results of ethnobotanical information, nutritional analyses and feeding trials will indicate which plants are best suited for human fare. Home economics testing will determine which plant foods are most adaptable to modern tastes and cooking techniques. Nutritionists with intercultural experience can create palatable recipes applicable to a range of cuisines. This helps introduce new foods to the public and to food industries through publication of recipes and cookbooks, popular media presentations, and demonstrations. Taste testing is an important step in the final introduction of a food.

MESQUITE AS AN EXAMPLE OF A NEW CROP

The mesquites (*Prosopis* section *Algarobia*) are used to illustrate the development of a promising new crop. In our opinion certain of the *Algarobia* will become major world agronomic crops.

Phase I

In southwestern North America the *Algarobia* are known as mesquite or *mezquite*, and in South America the term *algarrobo* is applied to most of the species. In both North and South America they served as major resources for the native peoples (D'Antoni and Solbrig 1977, Felger 1977). In southwestern North America mesquite was the single most important resource plant for the indigenous peoples (Bell and Castetter 1937, Felger 1977). It was exploited as a major source of food, medicine, fuel, shelter, weapons, tools, cordage, dye, pitch, and numerous other practical and aesthetic purposes. Our studies of mesquite in Sonora and Arizona primarily involve velvet mesquite (*Prosopis velutina* Wooton) and western honey mesquite [*P. glandulosa* Torr. var. *torreyana* (L. Bens.) M.C Johnst.].

The primary food product from mesquite is from the seed pod. Significantly it is indehiscent, so it can be harvested without loss of the contents. The pod is comprised of exocarp, mesocarp, endocarp, and seed. The exocarp and endocarp are inedible, but might be used for fuel or fiber. The mesocarp, the mealy pulp of the pod, is rich in carbohydrate but low in protein. The seed, enclosed by the tough, hard endocarp or pit, has a very high protein content (table 1).

Although there were many variations on methods of preparation, the pods were usually parched or otherwise dried, ground or pulverized, and the mesocarp flour mixed with water and made into a cake-like bread or beverage. It was also fermented into alcoholic beverages. Mesquite cake was air dried, no cooking was necessary.

There is considerable geographic and local variation in sugar content of the pod. The Seri, Gila River Pima, and other Indian peoples knew of superior tasting and high yielding groves and individual trees which were specifically sought out each year (Felger 1977).

The difficulty with separating the seed from the encasing hard endocarp limited the use of the seed. However, various ancient peoples, such as the prehistoric inhabitants of the Pinacate region of Sonora devised stone gyratory crushers which can still be used to grind large quantities of the mesocarp into flour as well as break open the endocarp to free the seed (Felger and Nabhan 1976, Hayden 1969). Modern industrial gyratory crushers or hammer mills can be adapted to process large quantities of mesquite pods.

Phase II

One of the crucial questions in developing a new crop is to determine how much it produces per unit area, and the factors influencing the yields. Study sites need to be chosen taking into consideration access and protection from commercial development or vandalism, yet allow study of the natural range of variability and potential limiting factors. For this reason, we prefer to establish study sites on protected lands. During the past five years, Cornejo and Felger have measured yields from several hundred desert legume trees and shrubs in Sonora and Arizona, mostly in remote places. In that period more than 10% of the trees not on protected lands were destroyed by man.

Sampling stations are set up across the Sonoran Desert representing gradients in the major environmental parameters such as temperature and rainfall, as well as seasonality and predictability of these parameters. For honey mesquite, we have study sites in the vicinity of Yuma, Arizona, and Kino Bay, Sonora, representing a northern and a southern location. For velvet mesquite, our primary study sites are near Tucson, with relatively more precipitation and freezing temperatures in winter, and near Sells, Arizona, representing a relatively drier site with less frost. Unfortunately, the majority of the great mesquite *bosques* or forests have been lost with the general destruction of riparian habitats.

At each station the number of pods per tree are counted from a sample of at least 15 trees. Ideally the sample would contain 30 individuals, but we have used a smaller sample size because of the time involved in counting, and the number of study sites and species being worked during each season. Also, most of the quantitative data must be obtained during a relatively short time span, mostly in early summer.

The population near Kino Bay was selected because of the extensive ethnobotanical information relating to the site (e.g., Felger and Moser 1971). Normal, healthy appearing trees are chosen for the sample. Each one is marked with an inconspicuous metal tag, and a map made of the tagged trees. Conspicuous labels draw attention to the trees and are more likely to be vandalized. Most of the large desert perennials we are studying

produce their crop of fruit during the hottest, driest time of year, during June and July. For health and comfort, sampling is generally done in the early morning. The number of pods are recorded with the aid of a small hand counter. We have found it best to count all of the pods directly in the field, and have not found any time saving or increased accuracy by extrapolating from a partial count of each tree or by using pod traps.

Before counting, the ground and brush is inspected for rattlesnakes because one is looking up while counting. The larger, better yielding honey mesquite trees may have a standing crop of 15,000 to 25,000 pods (table 2). With experience, each of these trees can be counted in about 45-60 minutes. Of course, many trees will have fewer pods, and during some years, many of the trees will have very few or no pods. The velvet mesquite trees we have been sampling usually have a maximum of 8,000 to 13,000 pods, and each tree can be counted in about 30 to 45 minutes.

Counting the same tree each year provides data for long term yields. As might be expected, soil moisture is a primary factor influencing yields, although the same tree seldom produces a very high yield for more than two years at a time (Cornejo and Felger, in prep.). However, it is apparent that other factors are also significant. For example, unseasonally cool weather during flowering may reduce the activity and effectiveness of the pollinators. For the major Sonoran Desert tree legumes, this is particularly important since they are insect pollinated. For example, foothill palo verde (Cercidium microphyllum) produced massive flowering in mid-April, 1980, near Tucson. Fruit set, however, was generally poor, and we attribute this largely to several weeks of unseasonally cool weather at that time.

A sample of 40 to 60 pods is collected from each tree counted. The fruit is put into a dry paper bag, brought back to the laboratory, oven dried, and weighed. After weighing the entire pods, they are broken into mesocarp and seed and weighed separately. Infestation of seed beetles (Bruchidae) is a major problem with many legumes, particularly those from tropical and desert regions. For this reason, the pods are treated as soon as possible with heat, freezing, or stored with an effective insecticide.

Among the parameters being recorded are absolute size (weight) of the entire pod, ratio of seed to mesocarp, number of seeds per pod, and seed weights. In most cases the variation is sufficient to warrant increased sample size in order to better evaluate the observed variance. It is apparent that environmentally influenced or phenotypic variation in mesquite is great, although there are trends which also indicate genetic variation. For example, velvet mesquite seeds are significantly larger than those of western honey mesquite (table 2). There is also considerable variation in total pod weight and sugar content of the mesocarp. Year to year variation in a single tree is sometimes as great as variation among different individual trees measured the same year. Ultimately, samples need to be cultivated under standardized conditions to determine genotypes and study phenotypic ranges.

Actual yield per unit area is determined by calculating the density of trees at each study site and average weight of pods per tree. Calculations can also be made to determine the amount of similar or suitable habitat within a larger area, such as a county. In this manner, large scale productivity or yields can be determined. This may be useful in assessing optimum uses of public lands.

In a desert region, a study of this nature needs to be carried out over a number of years because of large annual variation in productivity. Ultimately, the observed variations can be correlated with environmental factors such as rainfall and temperature.

Phase III

Since we are interested in developing new agricultural crops, it is useful to extrapolate the observed actual yields to orchard or agricultural conditions. Although these extrapolations need to be interpreted with caution, gross predictions can be made. These extrapolations are valid because there is a statistically significant correlation (at the 99% level for velvet mesquite) for the regression between tree size and yields of pods produced for all of the desert tree legumes studied (Cornejo and Felger in prep). Size of tree is represented as diameter of crown and yield as total weight of pods per tree.

Extrapolations to orchard conditions are based on data from the Tucson region for 1978 (Cornejo and Felger in prep). In this case, the diameter of a tree is x and the number of pods is y so that a model II regression can be written:

$$y = 1245.3(x) - 3287.4$$
$$(r = 0.68,\ n = 13)$$

If we take one of the higher yielding trees, the regression equation becomes:

$$y = 1245.3(x) - 971.3$$

In our theoretical orchard, the trees would be 8 m in diameter with 2.5 m between rows. This yields 118 trees/ ha. The calculated yield for velvet mesquite is 8,985 pods/tree or 1,063,290 pods/ha. The average dry weight of a pod is 2.17 g thus yielding 2,308 kg/ha. This yield represents what may be physiologically probable for trees planted in the proposed orchard densities. Some supplementary watering might be necessary in certain areas to produce these yields. However, through artificial selection these yields can undoubtedly be greatly improved.

This information allows us to design optimum crop geometry or spacing of the trees and rows. However, other factors also need to be taken into

Table 2.--Yields of mesquite pods and seeds for 1978 from Tucson, Arizona, and Kino Bay, Sonora. Data from Cornejo and Felger (in prep).

	Pods per tree x (n)	Pod wt. (g) x ± S. D.[a] (n)	Mean wt. pods per tree (kg)	Seed wt. (g) x ± S. D. (n)	Mean wt. seeds per tree (kg)	mean tree diam. (m)
P. velutina (Tucson)	5,000 (7)	2.2 ± 0.66 (7)[b]	10.86	0.043 ± 0.0104 (7)[c]	3.25	6.65
P. glandulosa (Kino)	6,752 (6)	2.4 ± 0.42 (6)[d]	16.07	0.032 ± 0.0047 (6)[e]	3.01	11.3

a = standard deviation with corrected denominator of n-1.
b = 7 trees with a total sample of 210 pods.
c = 7 trees with a total sample of 1,054 seeds.
d = 6 trees with a total sample of 180 pods.
e = 6 trees with a total sample of 710 seeds.

account. Higher yields might be obtained by periodically copicing the trees, or biomass (wood) might be one of the desired products. It then might be desirable to closely space the trees to obtain tall, straight trunks. Multiple cropping to more closely simulate natural ecosystems would also influence orchard geometry.

There should be considerable hybridization potential, with approximately 20 species of *Algarobia* in South America and 6 in North America (Burkhart and Simpson 1977). Putative, natural hybrids have been reported for South America (Hunziker et al 1975) and we have found indications of hybridization between *P. glandulosa* var. *torreyana* and *P. velutina*. The wide range of variation indicates a plastic genome suitable for substantial selection and genetic manipulation. We predict that mesquite will become a major world crop.

The several species of mesquite in the Sonoran Desert may be taken as examples of the agronomic potential to be realized by surveying the world's flora. We predict there are several dozen species of plants among the Sonoran Desert flora suitable for development as major crops, and several thousand world wide. Survey and development of the world's promising new crops has hardly begun. The results may have world-wide economic, social, and ecological impacts.

SUMMARY

A method is presented for inventorying and developing new plant resources. This system consists of three phases which are logical subdivisions of personnel, facilities, and methods. Phase I includes identification of species that could be important to our technologically-dependent society. The methodology is largely fieldwork and appraisal of existing information. Phase II consists of locating plant populations, studying productivity, pollination ecology, environmental and genetic variation, field sampling, and proximate chemical analyses, to determine if a taxon is suitable for modern agriculture. In Phase III, we are concerned with cultivation and domestication, and includes field plantings, genetic selections, hybridizations, detailed chemical analyses, animal feeding trials, and experimental preparations. Our plan is based on a multidisciplinary international approach. The phases can be conducted independently for different target plants. Most importantly, this system of plant resource inventory and development is transferable to other regions. World-wide research and development of diverse, ecologically adapted new crops has hardly begun.

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RESUMEN

Esta presentación enfoca principalmente los métodos de inventariar, estudiar y desarollar el potencial de plantas como fuentes de nutrición humana y de forraje así tanto como explorar usos múltiples derivados de ellas. La investigación se orienta a la adaptación de plantas del Desierto Sonorense de uso potencial a la tecnología de la agricultura moderna. Interesan especialmente aquellas plantas utilizadas milenariamente por modadores indigenas de la región. Los conceptos y la metodología que proponemos pudieran ser utilizadas como modelo para investigación y desarollo en otros climas y con cultivos de otro potencil no nutritivo.

Una gran variedad de plantas nativas pueden suministrar importantes cultivos adaptados a las condiciones locales. La incrementante desertificación del Desierto Sonorense señala la necesidad urgente de inventariar los recursos botánicos y preservar germoplasma de ciertas plantas adaptadas al medio desértico. Nuestro énfasis principal es el de desarollar cultivos locales adaptados de las especies indígenas que crecen con una mínima cantidad de agua y de insumo de energía e inclusive con riego de agua salada. El repertorio de nuevos cultivos bajo consideración incluye docenas de especies de diversos grupos de plantas. Estos grupos abarcan especies de 1/ árboles y arbustos (e.g. *Cercidium*, *Prosopis*), 2/ perennes de raiz (e.g. *Amoreuxia*, *Cnidoscolus*), 3/ efímeras del desierto (e.g. *Amaranthus*, *Lesquerella*), 4/ zacates salados (e.g. *Distichlis*) y 5/ los zacates del mar (e.g. *Zostera*).

La metodología se divide en tres etapas resultado de una división lógica de personal, instalaciones, y métodos. Las etapas son: 1/ inventario inicial e identificación de especies que pudieran ser importantes para nuestra sociedad tan altamente dependiente de la tecnología, 2/ evaluación inicial, estudios ecológicos y análisis químico y estudios nutricionales para determinar si un determinado taxon es apropiado para someterse a los sistemos modernos de agricultura, 3/ el cultivo y domesticación, incluyendo plantíos experimentales, selección genética, hybrización, análisis químicos específicos, nutrición animal, y preparaciones experimentales.

La metodología se basa en un agroecosistema de la región del desierto empleando un plan de historia natural. La investigación y desarollo es multidisciplinario e internacional. El concepto funadamental es el de desarollar cultivos adaptados al medio ambiente en vez de cambiar el medio ambiente para adaptarlo al cultivo. La investigación y el desarollo a nivel mundial de cultivos diversificados ecologicamente adaptados apenas se ha iniciado.

Inventory Approaches to Range Management Studies[1]

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Francisco J. Sifuentes-Resendiz[2]

Abstract.-- Three resource inventory approaches used in Northern Mexico rangelands are presented and discussed: 1) Range site evaluation, 2) Ecosystem clinical methodology and 3) Reference units. The application of these approaches, however, depends on the objectives, nature and scope of the study.

INTRODUCTION

Rangelands cover a large portion of the earth and as such, form an inmense reservoir of basic resources which indirectly influence our complicated civilization. In Mexico the highest use of these lands for human welfare is often animal grazing , but rain-fed farming and gathering of native plant products are two main complementary activities. Studies, which are designed primarily to cope with the complex problems of rangeland use, are almost always dependent upon an inventory of resources as the most essential element in a wise planning scheme (Medina and Nava, 1977). The need for such inventory is clearly indicated since delineation of resource capabilities aids materially in land classification for major uses such as agriculture, forestry, grazing, recreation, and the evaluation of these uses in terms of social and economic needs.

To attain success as a manipulator of natural ecosystems, the range manager must have a certain level of knowledge of the physical and biological characteristics. In addition, he must understand the complex interactions between the physical, ecological, social, and economic factors that constrain the aplicability of a given range management alternative (Bartlett et al, 1979). A potential land-use activity needs to meet the particular physical and ecological requirements of the area, fit into the social structure and cultural context of the region, and stay within the economic and financial constraints (Fig.1).

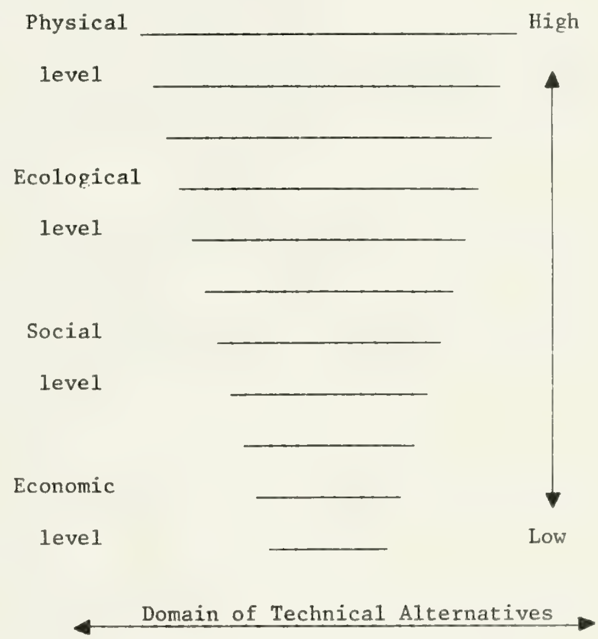

Figure 1.-- Levels for decision-making in range resources problems (Nava et al, 1979).

RANGE SITES

A basic unit of land classification that has been applied in range evaluations in the United States and Mexico is the range site. According to the Range Term

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Glossary of the Society For Range Management a range site is an area of land having a combination of edaphic, climatic, topographic and natural biotic factors that is significantly different from adjacent areas (Huss, 1964). One site is distinct from another if it presents significant differences in potential forage production and/or differences in management requirements for proper use (Shiflet, 1973).

Range managers consider a range site as the main resource unit from which basic information is gathered for production-oriented plans. Conceptually a range site represents the data base to integrate information with respect to resource capabilities and expected biological responses from different land use treatments. It is the range site level where the manager and the researcher can correlate treatments and results and, thus, make sense from otherwise unrelated data (Ogden, 1975).

Appraisal of the forage resources and determination of the grazing capacity of rangelands are two of the main objectives of range site inventories (Stoddart et al, 1975). This implies delineating, mapping, and sampling at the range site level. Sometimes range sites within an ecological region or even within a particular ranch are large enough that they might be mapped and managed as separate entities, but frequently they appear in such a pattern that only complexes of sites can be mapped, as can be observed in the arid and semiarid zones.

Analysis of range resources by field inventorists to determine the present condition and potential involves the following aspects:

Plant composition of each range site for their different conditions.

Soils and their main features with relation to grazing.

Topography for determining potential use of the site and harvesting problems.

Infrastructure availability and future needs such as fencing, roads, watering and salting.

Range site area within every pasture and its forage production potential.

This last is an important feature, especially for Mexican rangelands under the private property tenure system, which limits the extension of the grazing unit according to the potential productivity.

If inventorists ignore sites and work in a generalized way, say to a municipal or a regional level, decisions about ecological management of the ecosystems are also generalized. Information could have a wide margin of technical error and offer relatively low possibilities of application.

Data Needs

Planning the multiple use of desert range vegetation and related resources for various productive activities as livestock, fiber, wax, rubber, fruits and food, requires the collection of a variety of data about the physical and biological properties of the ecosystem components. Basically, three different inventory types could be applied for collection of the information needed: Physical Inventory, Operation Inventory, and Socioeconomic Inventory. A general discussion of these approaches follows.

Physical Inventory

The physical inventory is concerned with the collection of information on tangible objects including:

Rangeland resources availability and characteristics

Climate and its main features

Forage and its main ecological and economic perspectives

Water availability and level of development of the resources

Infrastructure, including needs to support a given management and utilization program.

Operation Inventory

The operation inventory allows the analysis of the present system of operation and management in order to visualize what could be achieved to increase production efficiency. As an example, the following items are commonly evaluated:

Livestock inventory and its main features

Supplemental feeding, costs, supplies, and observed results.

Livestock and routine management

Commercial aspects

Other land uses.

Economic And Social Inventory

A socioeconomic inventory involves the collection of information about the economic status of the productive unit (private land, ejido, or other), including, among others, the following:

Number of land-dependent families

Financial analysis

Social and technical organization and membership

Education level

Possibilities for private of official funding

Once the information is collected, analysed, and a diagnosis is made, man, as an ecosystem manipulator, must be capable of planning for the optimum use of natural resources. This way plans should be periodically revised and modified according to society's requirements.

Inventorists have to be concerned with the special behavior of rural people in the zone of influence. They have to be experienced enough to analyze the information gathered and to suggest potential uses on a sound technical basis. This means that they have to define the correct use, single or combined, of every range site according to the social and economic status of the region.

ECOSYSTEM CLINICAL METHODOLOGY

The comprehension and solution of a range problem begins with a detailed evaluation of the different components of the ecosystem involved. The development of an approach to study such components was undertaken by Maynes et al, (1975).

Clinical methodology is a general procedure to define the sequence and characteristics of the steps involved in the study of ecosystems and the transformation from their initial state to an optimal state.

This process is called clinical methodology because the ecosystem is viewed as an ecological patient, whose state may be normal or abnormal depending on whether or not its function corresponds to a given level of man-channeled productivity.

This methodology consists of six successive and coordinated steps: Clinical examination, Diagnosis, Treatment, Strategy, Implementation, and Validation.

The approach is based on two assumptions:

1) The existence of an optimal state which can be defined by anthropic criteria, and

2) The feasibility for directing the proposed change of the ecosystem towards the optimal state.

Clinical Examination

Clinical examination is the study, observation and measurement of signals, from whose analysis, some characteristics of the function and structure of the ecosystem is inferred. The process starts with the selection and measurement of state variables, i.e., the observed attributes of the ecosystem (Gastó et al, 1976).

First, a general description of the range is undertaken including geographical location, climate, physiography, land use history, disturbances and others. Second, more specific and detailed information is gathered in the field for the following basic components:

Abiotic Resources

Abiotic resources comprise elements such as water, light energy, oxygen, nitrogen, soil minerals, and carbon dioxide that are used by plant organisms to build up their vital structures.

Habitat

It comprises the abiotic attributes that catalyze or constrain the biological processes such as water potential, ion concentration, thermic level, air pressure, light intensity, and wind velocity.

Heterotrophs

This category represents the set of consumer organisms either plants or animals.

Autotrophs

This category corresponds to the photosynthetic organisms.

The examination is made iteratively with the diagnosis, for the measured variables will primarly serve as diagnostic variables. Some of the criteria for selecting the variables to be measured are (Nava et al, 1979):

Prediction of the entirety of the possible variables to be measured

Determination of the required variables and to measure only these

Determination of the maximum allowed time to be employed in the examination, and to measure all variables that can be quantified in this time lapse

Determination of the maximum effort or work to be employed in the examination, and to measure all variables that can be quantified with this effort.

Diagnosis

The Random House Dictionary defines diagnosis as the process of determining by examination the nature and circumstances of a diseased condition. This is, the set of signals that determines the particular characteristics of a disease. The diagnosis comprises two basic steps: 1) Arrangement of the information collected through the clinical examination and field work, and 2) assessment of this information.

The relative importance of a signal is listed and classified according to its hierarchy. Then a differential diagnosis is made by comparing the symptoms of the patient with a list of ecological diseases, eliminating those that do not correspond to the patient's symptoms. Finally a verdict is made, indicating the correspond ing disease; if doubt persists, more information is collected.

An intermediate step between the diagnosis and the treatment is the pretreatment prognosis, i.e., the forecast of the possible course of a disease. It is the prediction made to the ecological patient after the diagnosis, but before recommending a treatment.

Treatment

A treatment corresponds to the method or system employed to cure a disease. It comprises the set of steps supposedly needed to direct the change of the present state of the range ecosystem toward an optimal or more preferred state.

Strategy

A strategy is the science and art of projecting and directing the application of something, in our case, of the recommended treatment. More than an ecological problem, the strategy is a social and economic concern. For each treatment there exists a wide gamut of logical application alternatives.

Implementation

The implementation corresponds to the application of the treatment according to the projected strategy.

Validation

The validation or verification is the last phase of the clinical methodology analysis of an ecosystem. The main objective of this step is to verify the results of the clinical process.

REFERENCE UNITS

The reference units approach is based upon the concept ot ecosystem transformation (Armijo et al, 1977). This approach is intended to obtain several alternatives of transformation for each ecological unit of the ecosystem.

In particular and within the framework of the ecosystem clinical methodology (May nes et al, 1975), the determination of the more feasible units of transformation depends on the present state and on the optimal or goal state of the ecosystem. The feasible units are called reference units, for they form the elements designed by the diagnosis.

The present state of a range system is expresed in terms of the inputs received by the ecosystem. The criteria to define this state are the density, frequency, and cover of the dominant species.

The present state is determined by aerial photographs and with field reconnaissance, identifying the different vegetation types on each study area.

The goal state corresponds to a combination of value and ecological judgments that are stated in the form of a hypothesis.

The elements of judgment used to construct the goal state are the following (Gutierrez et al, 1979).

Ecological criteria

Geomorphology

The main variables used are the shape and degree of slope of the geomorphological units. Several units are identified such as alluvial and colluvial valleys, piedmont foothills, and mountains

Vegetation

This involves the present distribution of the species, considering that some of

them are native and others are invaders.

Soil

Factors evaluated are the degree of erosion, landscape position, and effective depth of soil.

Value criteria

Resource Multiple Use

Given the various alternatives of potential use of the existing species, several categories are considered, i.e., industrial, forage, food and wood-producing plants.

Stability

This criteria groups some considerations and strategies of production that may allow a better use of the erratic distribution of rain.

Costs

This category includes the main costs of formation, operation and harvest of resources.

Consistency

To keep an affinity with tradition and culture of regional dwellers, the traditional activities are emphasized.

Data Needs

The reference units approach includes only biogeostructural aspects due mainly to the great complexity of the work. For that reason several assumptions that tend to simplify and clarify the idea of the study are involved. A general procedure in the reference units approach is as follows:

Define vegetation units in the study area using aerial photographs

Check these units through a field reconnaissance

Find the geomorphological units and the soil classes

Define a set of projects (management alternatives) that can be implemented for each reference unit

Evaluate the possible impact of each project and select those that can satisfy the objectives

Implement, if it is neccesary, modifications to the selected projects. If, so return to define a set of projects.

Implement the projects in the area

Evaluate the implemented projects.

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ALTERNATIVAS DE INVENTARIO PARA EL ESTUDIO DEL MANEJO DE PASTIZALES[1]

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La planeación del uso de un pastizal implica el conocimiento detallado de los recursos con los cuales se cuenta y con los cuales se va a operar. Se requiere de un inventario completo que permita lograr un entendimiento del potencial y límites de los recursos y que al final permita tomar decisiones lo más adecuadamente posible. Una actividad potencial de mejoramiento del pastizal necesita satisfacer los requerimientos físicos y ecológicos del área, adecuarse a la estructura social y contexto cultural de la región, y ubicarse, dentro de las restricciones económicas y financieras. En el presente trabajo se discuten tres enfoques de inventario que se han utilizado en los pastizales del Norte de México por un grupo de investigadores de la Universidad Autónoma Agraria "Antonio Narro"; 1) Sitios de pastizal, 2) Metodología Clínica Ecosistémica y 3) Unidades de Referencia.

Un sitio de pastizal es la unidad básica de clasificación de la tierra que se ha utilizado extensamente en México, y los Estados Unidos. En la ausencia de disturbios anormales o deterioro físico, un sitio de pastizal presenta una comunidad de plantas caracterizada por una asociación de especies diferentes de la de otros sitios en términos de la clase y proporción de especies o en el rendimiento total anual, de tal manera que se requieran algunas variaciones en su manejo. Dependiendo del objeto del inventario de sitios de pastizal, tres tipos de inventarios pueden realizarse: Inventario Físico, Inventario de Operación e Inventario Económico.

Al inventario físico le concierne la colección de información sobre objetos tangibles tales como los recursos de tierra disponibles, clima, forraje, agua e infraestructura. El inventario de operación se realiza para analizar la operación y prácticas de manejo actuales, antes de elaborar cualquier plan de manejo alterno. Entre otras cosas, se realiza un inventario del ganado doméstico, suplementos, prácticas de manejo del ganado y demandas interrelacionadas de la tierra. El inventario económico involucra la colección de información sobre el estado económico de la unidad productiva.

La metodología clínica ecosistémica es un procedimiento general para definir la secuencia y características de los pasos involucrados en el estudio de ecosistemas de pastizales y su transformación a un estado más óptimo. El pastizal es considerado como un paciente ecológico cuyo estado puede ser normal o anormal. Esta metodología consiste en seis etapas sucesivas y coordinadas: examen, diagnóstico, tratamiento, estrategia, ejecución y comprobación.

El enfoque de unidades de referencia se basa en el concepto de transformación de ecosistemas y tiene como objeto el obtener diversas alternativas de transformación para cada unidad ecológica del pastizal. El estado óptimo del pastizal es definido en base a criterios ecológicos y valorativos. El criterio ecológico involucra la geomorfología, el suelo, la vegetación, mientras que el criterio valorativo incluye el uso múltiple de los recursos, la estabilidad del ecosistema, costos y la congruencia o afinidad del uso de la tierra.

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[1]Trabajo presentado en el Taller de Trabajo de Inventarios de Recursos de Tierras Aridas: Desarrollo de métodos eficientes en costos, La Paz, B.C., México, Noviembre 30-Diciembre 6, 1980.

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Use of the Recreation Opportunity Planning System to Inventory Recreation Opportunities of Arid Lands[1]

Perry J. Brown, B. L. Driver, and Joseph K. Berry[2]

Abstract.--Recreation opportunity planning, which is being adopted by some land management agencies for recreation input to land management planning, is reviewed for its applicability to arid land situations. Particular attention is given to the inventory and analysis phases of the system and to what we have learned about its implementation during its development.

Recreation use of arid lands in the USA is growing rapidly. Those lands provide many recreational opportunities which range from primitive and unconfined forms of recreation through those forms provided at tourist resorts. They also provide unique recreational opportunities in distinctive landscapes with widely appealing and rather predictable climates. Pressures of increasing use have caused arid land managers to intensify their recreation planning and management activities on areas such as the deserts of southern California and western Arizona and the canyonlands of southern Utah. These resource managers, like their counterparts in more temperate environments, need planning and management techniques which enable better assessment and evaluation of recreation resource capabilities, integration of recreation with other resource uses, and management of the resources for recreation. Recreation opportunity planning, using the recreation opportunity spectrum concept, can help meet these needs of planners and managers of arid lands.

Recreation opportunity planning is an activity within the recreation production and evaluation process and it enables the rational allocation and management of recreation resources. To gain a more complete understanding of recreation opportunity planning we will review this production and evaluation process to show where recreation opportunity planning fits within it.

At a national outdoor recreation outputs workshop conducted at Harpers Ferry in West Virginia, an attempt to define this production and evaluation process was made.[3] A simplified diagram of this process is shown in figure 1 and is briefly discussed below.

The production of recreation opportunities begins with primary resources of land, labor, and capital. These resources are used in management actions such as building trails, constructing camping facilities, grazing domestic livestock, and providing sanitation and information services. Each action has an influence on the type, amount, and quality of recreation opportunity that is provided. In combination such actions (or non-actions) create the environment for recreation and thus the activity opportunities available and the probable experiences that will be realized. They, therefore, create the recreation opportunities supplied or produced. In this way, management actions are used to transform basic resources into recreation opportunities which recreationists then use to produce specific recreation experiences.

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[1]Paper presented at the workshop on Arid land resource inventories: Developing cost-efficient methods. LaPaz, Mexico. November 30-December 6, 1980.

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[3]Driver, B. L. and D. Rosenthal. The outdoor recreation production process. Unpublished report. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

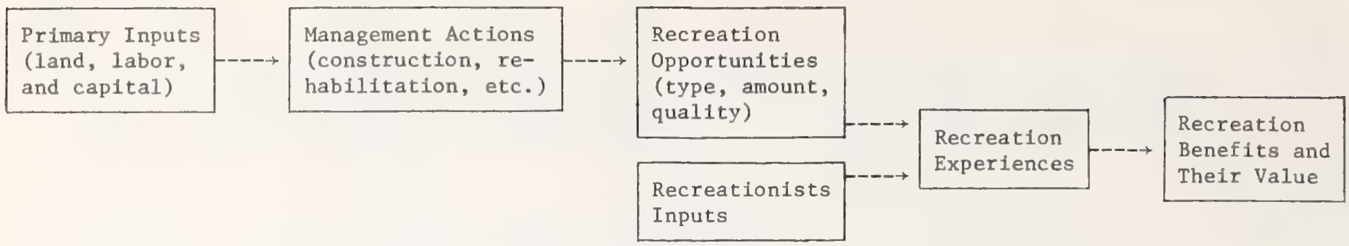

Figure 1.--The recreation opportunity production and evaluation process.

The recreationists' consumption of these recreation opportunities gives the reason for their production and provides an indication of the factors to be considered in defining the opportunities to be produced. In their consumption behavior (Driver and Tocher 1970, Brown, Dyer, and Whaley 1973, Hendee 1974, Driver and Brown 1975), recreationists are seen as coming to an area with specific expectations and desires for specific types of satisfaction. They engage in recreation activities at areas where they believe the combination of resource, social, and managerial characteristics that will enable them to realize their desires are offered. When they leave the area, they leave after having had experiences that, if satisfactory, will lead to subsequent personal and societal benefits.

The evaluation phase of the process defines the social worth of recreation opportunities and subsequent recreation experiences. It is used to identify and quantify the economic and non-economic individual and societal benefits of recreation opportunities and experiences.

Recreation opportunity planning provides a rational framework for determining how recreation opportunities should be produced. It focuses on the settings for recreation that are provided by management and that are used to deliver recreation opportunities to recreationists. It is a relatively new planning framework that is based on making the recreation opportunity spectrum an operational concept.[4]

INVENTORY FOR RECREATION OPPORTUNITY PLANNING

A recreation opportunity is the chance to engage in a recreation activity in a specific setting to realize a desired recreation experience. Recreation opportunity planning generates demand and supply information about the type, quantity, and quality of these recreation opportunities for use in resource allocation and management decision making. A primary feature of this planning is its arraying of the types of recreation opportunities along a spectrum. This recreation opportunity spectrum, at the most aggregated level, usually has been divided into five classes as shown in figure 2 (Driver and Brown 1978). The semi-primitive class often has been divided into two subclasses, semi-primitive motorized and semi-primitive non-motorized. This subclassification illustrates that any of the spectrum classes can be subdivided to meet the needs of decision makers.

Currently the most widely applied components of recreation opportunity planning are the inventory and analysis phases.[5] These portions of the planning system, with emphasis on arid lands, are the focus of the remainder of this paper.

The recreation opportunity inventory enables identification of current and potential types, amounts, and qualities of recreation opportunity (Brown, Driver and McConnell 1978). It begins with identification of the attributes of the recreational setting which need to be assessed. Those attributes which must usually be considered are:

1. roads, trails, and other transportation features
2. buildings and other man-made structures
3. sources of man-made sound
4. relatively irreversible evidences of man
5. renewable resource modifications
6. vegetation patterns and types
7. soil types
8. topographic relief
9. water bodies and channels
10. wildlife species, numbers and patterns
11. specific natural features enabling recreation activities

Modern-Urban	Rural	Roaded Natural	Semi-Primitive	Primitive

Figure 2.--A common division of the recreation opportunity spectrum.

[4]Building on ideas expressed by J.V.K. Wagar (1951), W.R. Burch, Jr. (1964), S.R. Tocher, J.D. Hunt, and J.A. Wagar (1965), and J.A. Wagar (1966), Driver and Brown (1978) and Clark and Stankey (1979) have provided the framework for making the recreation opportunity spectrum concept operational through recreation opportunity planning.

[5]An overview of the entire recreation opportunity planning system occurs in Brown (1979).

12. recreation user numbers, densities, and behaviors
13. recreation management activities being practiced
14. other land uses

Data on these attributes are used in recreation opportunity planning in several ways. For example, the planner often wants to know which recreation experiences (such as finding solitude, affiliating with family or friends, or self-testing) most likely can be realized at the present time by recreating on specific tracts of land. To obtain this information, data about transportation features, buildings and other man-made structures, sources of man-made sound, relatively irreversible evidences of man, renewable resource modifications, recreation use, and recreation management activities are combined. These data are then analyzed using specific standards which enable zoning a tract of land into one of the recreation opportunity spectrum classes. Each of these classes has inherent in it higher probabilities for some experiences than for other experiences. Alternatively, if the planner's interest is in the most probable potential recreation experiences, the planner can analyze data on the same attributes as for current recreation experiences, except for the last two, both of which define current conditions, not potential conditions. Or, if the planner is interested in identifying the potential for specific recreation activities, the requirements for each activity must be looked at. Recreation opportunity inventory can help do this by providing information about recreational features, such as slope, snow conditions, water bodies, and wildlife.

The planner's determination of quantity of each recreation opportunity available requires data on vegetation, soils, water, wildlife, specific recreational features, and recreational facilities. Based upon the ability of each attribute to support recreation, a judgment is made regarding the quantity of each recreation opportunity available. Determination of the quality of each recreation opportunity is most dependent upon information about specific recreational features and facilities.

Once information on <u>current</u> and <u>potential</u> recreation opportunity type, amount, and quality is assembled, the planner can determine production possibilities for different tracts of land. This can lead to development of resource use alternatives in either a single or multiple use framework.[6]

To date most use of recreation opportunity planning has occurred on temperate and semi-arid forest environments of North America. Only a few applications have been made in arid grass and desert lands (Brown, Driver, Bruns, and McConnell 1979). However, our experience with recreation opportunity planning, and particularly the inventory and analysis phases, suggests that the system is widely applicable to arid lands. Also, as recreation opportunity planning has been applied, we have learned how it can be improved when applied to arid and non-arid lands.

What have we been learning? One thing is that the attributes of the land and its management that need to be inventoried are the same for all types of landscapes. That is, for all lands we need to inventory the same kinds of features.

Another thing we have learned is that while the features to inventory do not vary by landscape, many of the standards that make these attributes useful in different settings do vary. For example, one of the criteria for delineating recreation opportunities is remoteness of the area from sights and sounds of man. In general this has been operationalized as a distance from roads and trails having motorized use.[7] In the forested areas of the central Rocky Mountains a distance of three miles is sufficient to delineate an area providing opportunity for primitive and unconfined recreation (Brown et al 1978). In the more densely stocked forests of the Pacific Northwest and the Eastern U.S.A., a standard of less than three miles is sufficient. And, in the grasslands and deserts of the Southwestern U.S.A. and northern Mexico, a distance of greater than three miles, possibly as many as five or six miles, is sometimes necessary to provide the same recreation opportunity. This greater distance is necessary to diffuse the sights and sounds of man where there are few natural obstructions, as across a relatively flat grassland. This means that for both grassland and desert environments having little topographic relief larger areas are needed to provide primitive and unconfined recreation opportunities than are needed for forested environments. Where the topography is more varied, as in a canyonlands type landscape, the distance standards used on arid environments appear to be closer to those used for forest landscapes, and thus smaller areas can provide the same recreation opportunities as larger areas of other arid lands.

Another finding has been that the quantities of many recreation opportunities are lower in arid

[6] A more complete description of how to do recreation opportunity planning as part of total land management planning will be available soon in Chapter 500 of the USDA Forest Service Land Management Planning Handbook (FSH 1909.12).

[7] Waterways with motorized use and railroads are included. Also, non transportation considerations dealing with visibility or audability of human works are used where distance from transportation routes does not indicate the degree of remoteness necessary. Data necessary to identify remoteness comes from inventory of transportation and other man-made features. The data are evaluated using specific remoteness standards for each recreation opportunity spectrum class.

environments than in temperate environments. This is particularly apparent in comparing temperate forests with arid forests, grasslands, or deserts. For example, capacity is limited for primitive and semi-primitive recreation opportunities because of limited screening of other people by vegetation. Quantity is also limited for more developed and motorized recreation opportunities because of lack of moisture, and its subsequent consequences, in arid landscapes. Additional potential limits on quantity and impacts of recreation on arid environments have been identified by Hunt (1977).

Another, but more subtle thing which we have learned is that some attributes used to define the quality of recreation opportunities differ between arid and temperate environments. For example, climatic factors are important in all landscapes but coolness of the temperature seems to be a particularly important attribute in arid environments used for recreation.

Another thing that we have learned about recreation opportunity planning is that once a planner adopts the logic of it, it is relatively easy and efficient to use, whether it is used in a temperate or arid environment. The logic is explicit, the criteria for identifying recreation opportunity areas are held to a minimum, and one can select the required precision for data collection and analysis based on the level and kind of decision to be made.

We have also discovered that when recreation opportunity planning is used on a regional or national scale, computerized data processing is desirable. Therefore, we have begun to adapt a general cartographic mapping system, called the Map Analysis Package (MAP) (Tomlin and Berry 1979) to our purposes (Berry and Brown 1980).[8]

The MAP computer software package consists of a system of primary computer operations which can be linked to produce a new synthesis of mapped data. It presently employs a grid-cell data structure for all analytical operations, though data may be input in many forms. Many primary computer operations are available in the MAP program although only a few of them were necessary for our application in recreation opportunity planning.

The cartographic model for addressing recreation opportunities enables generation of maps and tabular data on current and potential recreation opportunities. It presents the advantages of allowing large quantities of data to be stored and retrieved easily, and it enables preparation and reprocessing of maps much more quickly than if they are produced by hand drawing.

Our recreation opportunity cartographic model was developed and tested using a hypothetical data set. It is now being applied to an arid lands situation in the Steens Mountain area of eastern Oregon. Illustrative of the output of this recreation opportunity cartographic model are figures 3 and 4 which show current and potential recreation opportunities, respectively, for a 4500 hectare area using the hypothetical data set.

In producing figure 3 (current recreation opportunities), information about physical resources and their alteration by humans was combined with information about present recreational use and management activities. Figure 4 (potential recreation opportunities) was produced using only information about physical resources and their alternation by humans. In comparing these two figures we can see that present use and management characteristics have an effect upon the amount of semi-primitive and modern-urban opportunities that are presently provided. Presently less semi-primitive and more modern-urban opportunities are provided than would be determined by the character of the land base alone.

Other things learned from our current applications of recreation opportunity planning are that: (1) it can be easily adapted by different agencies, such as the U.S. Forest Service and the Bureau of Land Management, and thereby help establish a common recreation planning and management language

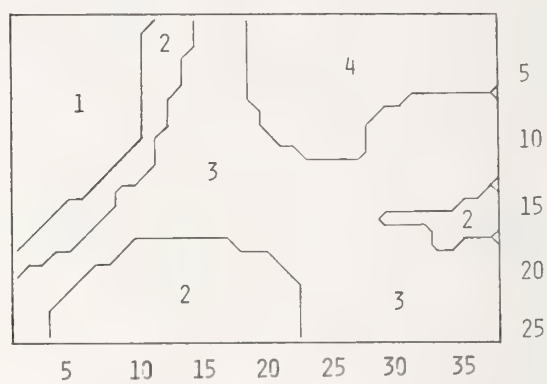

Figure 3.--Current recreation opportunities: (1) Modern-Urban, (2) Rural, (3) Roaded Natural, and (4) Semi-Primitive.

Figure 4.--Potential recreation opportunities: (1) Modern-Urban, (2) Rural, (3) Roaded Natural, and (4) Semi-Primitive.

[8] MAP is currently operational on IBM computers and is being adapted to CDC-CYBER computers.

across agencies; (2) the logic of the planning system is intuitively acceptable both to resource planners and to the public, such as when it is explained in public involvement review sessions; (3) the system provides improved bases and means for evaluating the impacts of different management activities on the type, quantity, and quality of recreation opportunities that can be provided; and (4) the concepts about the recreation opportunity spectrum which are used in recreation opportunity planning can also serve as guidelines for recreation resource management.

CONCLUSION

Recreation opportunity planning has been developed to provide a framework for making recreation inputs to land management planning. It is a planning process which fits within the broader recreation opportunity production and evaluation process and helps in making rational decisions about the allocation and management of recreation resources.

Our experience in using recreation opportunity planning, particularly its inventory and analysis phases, has indicated that it is widely applicable to arid land situations. Specific elements of the planning process do change, however, when it is applied to arid lands. For example, while the criteria for identifying types of recreation opportunity remain the same, their standards change when one moves from temperate to arid landscapes. Also, quantities of opportunity provided are often lower in arid environments than in temperate environments, and sometimes the factors considered in assessing quality of opportunity are different between arid and temperate environments.

A recent effort in development of tools for recreation opportunity planning has been development of the cartographic model which enables efficient storage, retrieval, and manipulation of mapped and tabulated data. This model is presently being tested in an arid lands situation in eastern Oregon.

Because recreation opportunity planning, including its inventory and analysis phases, fits within the general production and evaluation process that has been defined for recreation, and because it is a map based system that allows visualizing the impact of management actions on the type, amount, and quality of recreation opportunity provided, we feel the system has considerable promise for the recreation component of land management planning. Since both the USDA Forest Service and the USDI Bureau of Land Management are adopting the process, we expect its use to become even more widespread. It appears to be quite applicable to both temperate and arid landscapes.

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Resúmen: Se revisa, respecto a su aplicabilidad a zonas áridas, la planeación de la Oportunidad Recreative, la cual está siendo adoptada por algunas agencias relacionadas con el manejo de tierras con objeto de determinar el insumo recreativo en la planeación para el manejo de tierras. Se da particular atención a las fases de inventario y de análisis del sistema y a lo que hemos aprendido relativo a su implementación en el curso de su desarrollo.

Large Area, Low Cost Resource Inventories — Canadian Programs, Methods, and Costs[1]

D.M. Welch, T. Pierce and E.B. Wiken[2]

Abstract. --The Canada Land Inventory, Ecological Land Survey and the Northern Land Use Information Series are described. For large areas and at scales typically smaller than 1:100,000, these interdisciplinary inventories cost between \$1.00 and \$16.00/km^2. Ecological Land Survey is most recommended for developing an environmental data base for a wide variety of interpretations.

INTRODUCTION: SOCIO-POLITICAL BACKGROUND

"Canada is a few acres of snow and not worth a soldier's bones." So Voltaire is reputed to have written in the 1760's. A century later a Canadian industrialist suggested that we had become "hewers of wood and drawers of water." The two sayings reflect traditional and yet conflicting views of our place in the scheme of things - first a wasteland and then a resource-rich colony. Only since World War II have we developed from exploitation to resource management and the need for national and regional policies designed to yield maximum benefits to all social and economic sectors.

It is common nowadays to require of resource projects that environmental and social impacts be considered and that multi-resource development opportunities be taken in hand. This trend focusses on holistic planning and management, on inter- and intra-regional comparisons of environments, resource bases and societies, and on the consequent need for a multi-resouce data base upon which to influence public thinking, establish policy and base management decisions. Several methods for collecting such data have evolved in Canada. They are presented to this conference in the belief that our hinterland offers the same challenges to resource inventory as do arid lands.

CANADIAN PERSPECTIVES

The majority of 23 million Canadians live in urban and rural areas in the south. Areas which exceed Mexico, such as the Northwest Territories, contain a scant fraction of the population (table 1; fig. 1).

Intensive land uses, such as living, moving and food, wood and mineral production occupy one-tenth of Canada (table 1). Other measurable uses, such as mineral exploration, parks and reserves account for one-fifth of our land and freshwater. The remainder is largely "left" to water catchment, wildlife production and migration, native hunting, trapping and fishing, and various forms of wilderness recreation, although many contemporary and future economic developments are under consideration. Examples are oil and gas exploration, pipelines, national parks, commercial hunting of whales and of terrestrial and marine furbearers, and northern highways.

RESOURCE PLANNING IN CANADA

Land use and resource planning and management in Canada are subject to several jurisdictions. Any region or resource sector may fall within municipal,

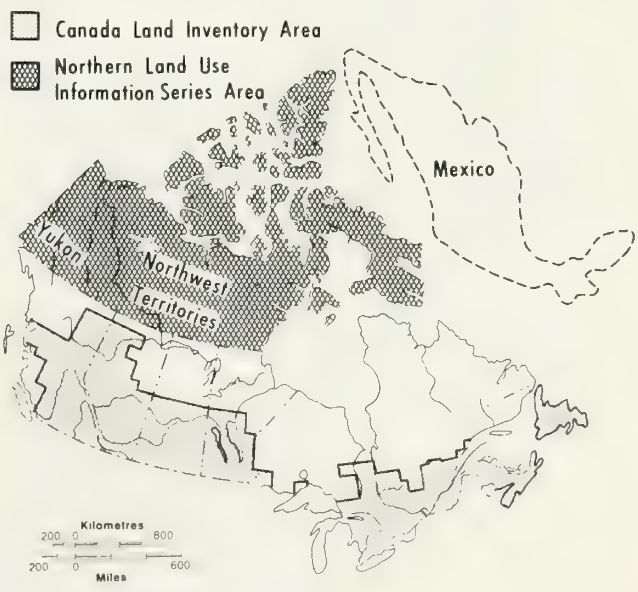

Figure 1.-- Canadian Perspectives.

[1]Paper presented at the Arid Land Resource Inventories workshop, La Paz, Mexico, Nov.30 - Dec.6, 1980.

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regional, provincial and/or federal mandates, some single resource and some multi-resource (spatial) in character. Thus resource development is often an adversary situation involving private industry, the public and several government agencies. Our experience shows that conflict can most easily be resolved through use of a common data base, whereby various resources are surveyed in comparable ways, leading to improved interdisciplinary and interagency understanding. The result is often a blend of improved environmental protection and increased development opportunity available as spin-offs from a major project.

Three examples of inventory of several resource sectors are discussed in this paper, (i) the Canada Land Inventory, (ii) Ecological Land Survey and (iii) the Northern Land Use Information Series. The first and third are specific programs, the second is a method applied to many different projects. All three involve several agencies or disciplines, and so offer lessons for organization and application of resource information bases. All three are conceived for or acceptable to national, provincial and broad regional policy formulation and planning.

Table 1.-- Canadian Perspectives

	Area (km^2)	Population (1978)
Canada	9,976,140	22,992,604
Mexico	1,972,537	66,940,000
Northwest Territories	3,379,683	42,609

Intensive Land Uses in Canada	
Agriculture, incl. pasture, woodlots	6.73%
Forestry, under private tenure	1.99%
Built-up, incl. buildings, excl. roads	0.16%
Transport, incl. urban roads	0.38%
Mineral and Energy Production	0.22%
	9.48%
Non-intensive Land Uses	
Parks, national and provincial	3.97%
Wildlife reserves, sanctuaries, conservation areas	5.69%
Mineral and Energy exploration	10.49%
	20.15%

THE CANADA LAND INVENTORY (CLI)

The CLI covers 2.46 million km^2 across southern Canada (fig.1) corresponding to the main settled areas and neighbouring fringes within climatic zones suited to agriculture. (Coombs and Thie, 1979). At a scale of 1:50,000 land was rated for capability for several uses, regardless of present use, other use capabilities, or economic or location factors such as tenure and distance to markets. Separate map series cover:

(i) soil capability for agriculture,
(ii) land capability for forestry,
(iii) land capability for recreation,
(iv) land capability for ungulates,
(v) land capability for waterfowl,
(vi) sportfish capability,
(vii) land use (1960's).

Each of the capability ratings extend from class 1, the "best" land for a particular use, downwards through classes of lower capability, usually to class 7 with negligable capability for a particular use. All except recreation are based on the concept of limiting factors, the number and severity of which cumulatively downgrade the land capability. Recreation is rated by opportunities and carrying capacity. Land use (late 1960's) is portrayed by 14 classes.

For each sector certain assumptions were made to help design the capability classifications. For example, forest capability rates the potential of the land for production of indigenous tree species grown at full stocking and assuming good management, but without physical improvements such as fertilization or drainage. For agriculture, the classes are rated for cereal crop production. Much of the capability rating was based on existing sectoral data and was done by scientists in that discipline and with working knowledge in a given province. The various classifications were developed through pilot field projects, followed by regional and national meetings of provincial, federal and university specialists.

In addition to the 1:50,000 field maps for each sector, generalized data are published at 1:250,000. In some areas Land Capability Analyses are published at 1:1,000,000 which show class 1-3 lands for several CLI sectors. Because of the volume (over 21,000) and complexity of maps, a computer system known as the Canada Geographic Information System was developed to store, analyze, combine or compare land data for all or part of Canada. This system provides 1:250,000 CLI data upon request, handles new data input by clients, and generates data for national and regional summary reports.

The CLI Method - Participation

The Canada Land Inventory required expertise from many persons, disciplines and agencies over more than a decade. A task of this magnitude required two critical ingredients for success: (i) clear roles for all participating agencies and (ii) good faith and cooperation between all individuals involved. Both of these depend on dialogue on the setting of objectives, terms of reference, methods, formats, etc. This does not mean that scientists and bureaucrats meddle in each other's affairs, but that each group communicates and listens effectively with the other.

Dialogue for the CLI began in 1961 when the federal government passed an Act enabling programs of farm consolidation, land improvement and land

use policy formulation by provincial governments. Through national symposia and parliamentary committees it became clear that these programs would be ill-founded without a good, national data base on land resources. Through 1961 to 1963 a series of regional, provincial and national conferences, including the Canadian Council of Resource Ministers, outlined and approved the terms of reference, overall methods and classifications of the CLI. Over 100 federal and provincial agencies, universities and private organizations became involved through these meetings and through pilot field projects.

The actual inventory work was conducted mainly through the late 1960's. Publication of maps, building of the computerized data system, and the generation of summary reports lasted throughout the 1970's. Thus even with widespread cooperation, a multi-resource inventory for an area greater than Mexico took two decades to complete. Throughout, the spirit of cooperation was maintained by active political and financial support from high levels of governments.

The Uses and Cost of the CLI

The Canada Land Inventory has had significant impact on our approach to land resource survey and policy in Canada, and has been widely used in planning, land management and development.

In Nova Scotia, New Brunswick and Prince Edward Island the CLI provided data to help formulate policy on adjustment of land holdings (e.g. farm consolidation) and rural economic policy. In three provinces, most notably British Columbia, it was used to designate Agricultural Land Reserves, farm areas protected from encroachment of conflicting land uses. In Ontario and Alberta the CLI was used in setting resource policy and regional development priorities.

More locally the CLI has been applied to land management and development, through:

- zoning to protect sensitive or significant resource areas or to avoid development on hazard lands;
- land acquisition for parks, conservation, farm amalgamation and land banking;
- compensation to land holders adversely affected by other developments such as surface mining or reservoirs;
- environmental impact assessments.

Perhaps the greatest benefit from the CLI is an intangible one - the growth of a national perspective and concern for our resource base. Many of the individuals involved have either become planners and policy makers or are involved in developing and conducting integrated resource inventories.

The many benefits of the CLI have been achieved at a cost of \$22½ million for data collection, \$7½ million for compilation, drafting, printing and distribution of generalized maps, and \$10 million for developing the computer support system and compiling the CLI data base. This translates to a unit cost of \$16/km^2 overall.

ECOLOGICAL LAND SURVEY (ELS)

Once the CLI was underway, planners and scientists involved with it realized the need for a land inventory system for the 7½ million km^2 outside the CLI area, one which would permit a wider variety of interpretations, and be applicable anywhere and at any scale. After several national committee and workshop meetings the system of biophysical land classification, now called ecological land classification, was developed. To provide national coordination of methods and terms, and to promote further development and use of ecological land classification, the Canada Committee on Ecological Land Classification (CCELC) was formed in 1976. Through the CCELC we have learned that land classification is not complete without proper terms of reference from the sponsor agency or without proper interpretation and application of the collected data. Thus we talk about Ecological Land <u>Survey</u> (ELS) as having three stages (Wiken, 1979).

The <u>Survey Proposal</u> is the first step of an ELS and yet, despite the CLI experience, the least addressed. In this step, the client(s) and the surveyor(s) must discuss the work to be done. The objectives and terms of reference must be resolved and become the same for both parties. If the dialogue is fruitful, the end-product of the survey will match in <u>D</u>etail, <u>T</u>ime and <u>S</u>cope, or DT'S. If there is insufficient dialogue, the client-surveyor relationship will not be clear and the results of the survey will likely be unsatisfactory. For example, there is no point in having the right detail and scope if the survey is completed after land use decisions are made. Equally, timely data is of little use if it lacks adequate information (scope).

<u>Ecological Land Classification</u> is the second stage of an ELS and is concerned with data gathering. The emphasis is on data useful for many purposes and which are keys in the framework of ecosystems. Depending on the detail required, aerial or satellite images are used to map ecosystem boundaries. Each map unit is described by data drawn from existing literature, field work and photo interpretation.

The size and variance of mapped ecosystems depends on the surveyor's perception of the land and the client needs (DT'S) to which he responds. Consequently a hierarchic system has evolved (table 2) which allows one to build onto existing surveys if more detail is needed subsequently. For example, once regional priorities are set using ecoregion or ecosection mapping in selected areas, detailed work is not necessary throughout large areas. Recognition of this principle greatly reduces survey

expenditures and increases benefits by providing more timely data to the planner or land manager.

Figure 2 shows the extent of large area ecological land classification in Canada to date. Hundreds of small area, detailed surveys have also been completed.

Ecological Land Evaluation is the third stage of an ELS and emphasizes use of the data base. Evaluations include interpretations such as land capability or suitability, multiple resource opportunities and compatible uses, environmental impacts, etc, as well as prescriptive and management plans for a variety of uses and scales. As such the data base must often be analyzed several times for each prospective use, depending on the rated importance (political, social, economic or environmental) of certain lands and resources.

Ecological land data can be analysed in several ways:

- holistic interpretations of all data for each mapped ecosystem;
- single factor, where the presence, absence or value of only one variable is relevant to a particular application;
- added factors, where capability, impact, etc. is a function of progressively increasing limitations (the CLI and many planning schools use this method);
- sorted factors, analogous to binary keys, although in land evaluation several "pathways" may lead to the same overall rating; and
- weighted factors, where several variables are weighted, scored and accumulated as a percentage rating for a particular use.

Figure 2.-- Levels of Ecological Land Classification in Canada to 1979.

Table 2.-- Levels of Ecological Land Classification

Level	Scale	Order of Planning
Ecoprovince	1:10,000,000 to 1:5,000,000	International, national and provincial
Ecoregion	1:3,000,000 to 1:1,000,000	Regional, sub-provincial
Ecodistrict	1:500,000 to 1:125,000	Sub-regional
Ecosection	1:250,000 to 1:50,000	Community
Ecosite	1:50,000 to 1:10,000	Detailed
Ecoelement	1:10,000 to 1:2,500	Site-specific

Uses and Costs of ELS

The uses of ELS are as diverse as the factors involved and the areas in which ELS has been conducted. Some examples are: resort development; wildlife inventory and habitat mapping; forest productivity; national park selection, planning and management; urban developments; environmental impact studies; reservoir and energy corridor siting; Indian reserve studies; etc. (CCELC, 1979).

Table 3 shows unit costs of some large area ELS's. These were conducted at the ecosection to ecoregion levels. For comparison, table 4 shows estimated unit costs for detailed, small area surveys. Unit costs are a function of three main factors. First is the scale of mapping; a doubling of scale require four times as much areal mapping (detail) and a comparable increase in ecologic information (scope) in order to maintain a matched set of DT'S. Secondly, the costs of northern flying vary greatly according to the needs of helicopters versus fixed-wing and the need for fuel caching in uninhabited areas.

Thirdly, we find that there is a threshold cost, for any survey, of about $25,000, representing salary and office overheads, report writing, printing and distribution. This up-front loading means that smaller surveys have higher unit costs.

Other cost factors are: the degree of research and development reflected in professional salaries (e.g. devising classifications, field cards); the requirements for data evaluation and presentation; and the availability of support services such as existing field camps versus establishment of new ones.

Excluding publication costs, we find that, as a rule, field operations take up 50% to 60% of an ELS budget, the remainder being professional and technical salaries and office overhead.

NORTHERN LAND USE INFORMATION SERIES (NLUIS)

Since 1971 the Northern Land Use Information Series of maps has developed into the major syste-

Table 3.-- Costs of Representative Large Area Ecological Land Surveys[1]

Title Date	Comments	Area km^2/yr	Principal Scale	Unit Cost[5] \$Can/km^2
Mackenzie Valley 1971-1974	Boreal, several settlements with easy access[2]	77,500	1:125,000	2.33
Melville Island 1975	Arctic tundra, one village, inaccessible[3]	15,500	1:125,000	8.90
Boothia Peninsula 1974	Arctic tundra, two villages, moderate access[4]	64,400	1:125,000	3.10
James Bay 1973-75	Mainly boreal, several towns, and hydro developments	117,000	1:125,000	7.74
Northern Manitoba 1975-76	Boreal. Several towns and villages, moderate access	62,640	1:125,000	3.48
Yukon Territory 1975	Mountainous, boreal to tundra, moderate access	536,327	1:1,000,000	0.18
Northern Yukon 1977	Alpine and arctic tundra Two DEW stations	35,000	1:500,000	1.43

1 Based mainly on reports in CCELC (1977)
2 Easy access means daily scheduled flights to main communities.
3 Inaccessible means no scheduled flights to the area.
4 Moderate access means weekly scheduled flights to at least one community.
5 Unadjusted for inflation - see date.

matic environmental and social research and information program for northern Canada (Taylor and Simpson-Lewis, 1977).

The maps are prepared and published at 1:250,000. To date the Series has covered 2½ million km^2 of the Yukon and Northwest Territories (fig. 1) and should complete its coverage during 1985, for a total of 4 million km^2. Information is presented in text and map form. The maps show a variety of land uses and wildlife habitats, archeological sites, terrain features of recreation interest, and native hunting and trapping areas. The accompanying text, about twice the space of the map, gives explanatory notes and supplementary information on climate, ecological characteristics and communities, etc.

The NLUIS was developed as a result of growing concern that we did not possess the tools required for comprehensive land management in the Canadian north. This concern was heightened by seismic and drilling programs in the Arctic, and the rush to begin construction of a Mackenzie Valley pipeline. While much information on the north was already available, it had never been systematically assimilated and made available to those with responsibility for activities on the land, from federal departments, through district wildlife officers to individuals living off the land. To fill this need, the federal departments of Environment and of Indian and Northern Affairs undertook to gather existing data, and summarize the results. Within the first year of mapping, however, a lack of significant baseline data was revealed, so that in 1972 the research was broadened to include field surveys of fish, wildlife and recreation-terrain opportunities.

From the original concept of the NLUIS arises a key feature of the program; its use of archives, published and unpublished scientific work, and the knowledge of local residents and community groups. While ensuring thorough and reliable inputs, this also fosters awareness of the maps by individuals and communities in an area. Furthermore it avoids duplicating scientific effort and so keeps unit costs remarkably low. For example fish and wildlife

Table 4.-- Estimated Costs of Small Area Ecological Land Surveys

Title	Typical Applications	Scale	Expected Cost\$Can/km^2
Semi-detailed regional planning	Location and design of development projects; type and intensity of land use	1:50,000	54
Detailed regional planning	New town location, impact assessments	1:25,000	247
Very detailed project and management	Subdivision site location, site management	1:10,000	927

research is contracted to territorial and federal agencies responsible for those sectors; costs to NLUIS are generally limited to field checking and compilation rather than primary data gathering.

Uses and Costs of the NLUIS

NLUIS maps are used principally by federal and territorial government staff in responding to applications for land use permits, for example to explore for oil, build airstrips or extract minerals. The maps help to specify the terms and conditions attached to a permit, or alternatively to define the needs for further environmental or social research. Industry and individuals often consult the maps prior to requesting a land use permit, so that confrontations are often avoided. The maps are also used in regional planning, environmental impact assessments, local game management and education of students and professionals, especially as familiarization for newly appointed resource managers.

The NLUIS is now in its 10th year. Because of inflation and the variable cost factors described for ELS, average annual costs are of little meaning. Currently, however, unit costs are about $\$1.20/km^2$, including all salaries, office expenditures and map printing as well as field programs, contracts and technical support services (table 5).

Like ELS, 55% of the budget goes to collect data including travel and salary of in-house staff. About 20% goes to compilation, editing and office overheads and 25% goes on map drafting and printing.

Since 1976 a rèconnaissance ecological land survey has replaced the recreation-terrain evaluation. The maps incorporate ecodistricts, giving information on terrain, soils, vegetation and water bodies. Because the survey is integrated with the other components, considerable savings are realized; the incremental cost of this portion is about $\$0.09/km^2$.

CONCLUSIONS

The Canadian experience in large area inventories shows that any single approach cannot be recommended, as each was designed under different circumstances. ELS is cost effective where a broad range of environmental matters must be addressed; it is also more flexible than the interpretative CLI program. The NLUIS blends ELS along with socio-cultural inventories to provide a data base on man-environment relationships.

Whichever approach is most appropriate, however, there are three principal considerations: a) The Importance of Dialogue on DT'S; an inventory must be timely; political, social and economic processes often move quickly. While in-depth research must take place, it is also true that the "best" information is useless if it comes too late. Continuing interaction between land classifiers and data users can help avoid the tendency of scientists to go into more and more detail. b) Flexibility; an ideal inventory should be widely interpretable, as often a data base, once available, is pressed into many more applications than were originally intended; c) Multi-resource inventory must be a coming together of professionals from several sciences, and is best performed when they work under the same roof, providing a mutual learning experience and maintaining a balanced inventory in line with user's needs.

If these considerations are met, large area inventories like the ones described here can play a vital role in national and regional planning. Such inventories help to priorize regions or resources for special concern, indicate development opportunities, provide for screening and initial evaluation of environmental impacts, act as a baseline for environmental monitoring, and establish a uniform framework within which detailed inventories can be focussed as needed. A major benefit is reduction of the high cost and time involved in a detailed inventory of large areas. The application of this principle through diverse environments in Canada shows that it is applicable also to arid lands.

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Table 5.-- Recent Costs of the Northern Land Use Information Series

Annual Budget $Can	Study Name Date	Comments	Area km^2	Unit Cost $\$Can/km^2$
$450,000	Central Keewatin 1979	Tundra. Several villages	330,873	1.03
$450,000	N. Baffin, Devon 1980	Arctic islands. Several villages	435,172 (incl.oceans)	1.36

INVENTARIOS DE RECURSOS DE BAJO COSTO EN GRANDES EXTENSIONES-PROGRAMAS CANADIENSES, METODOS Y COSTOS

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Si bien Canada no es un pais arido, tiene que hacer frente a muchas de la preocupaciones expresadas en el tema de la conferencia. Tierras situadas en latitudes remotas, tradicionalmente de bajo valor economico pero con presiones crecientes de los que abogan por zonas de recreo, y desarrollo energetico y de minerales, requieren proteccion arqueologica y ambiental, y se enfrentan a una percepcion politica creciente por los pueblos autoctonos y otros. La evaluacion del impacto que sobre la sociedad y el ambiente ejercerian la politica, planificacion y administracion de estas grandes extensiones, requiere una informacion interdisciplinaria sobre recursos renovables y caracteristicas ecologicas. Se han desarrollado diversos enfoques para recopilar y presentar este tipo de datos en Canada.

El mas conocido es el Inventario de Tierras Canadiense (ITC) que abarca 2,46 millones de km en el sur de Canada, y que corresponden a las principales zonas agricolas y habitadas. A escala de 1:50,000, se cartografio por separado la capacidad de la tierra para agricultura, silvicultura, ungulados, aves acuaticas, pesca deportiva y zonas de recreo al aire libre, utilizando entre 4 y 7 clases. El levantamiento cartografico del uso de la tierra (a finales de la decada de los 60) tambien se efectuo a esta escala, utilizando 14 clases. Si bien son accesibles al publico a la escala 1:50,000, se publican mapas de capacidad generalizados a escala 1:250,000 disponiendose de algunos mapas analiticos de multisector a escala 1:1,000,000. Los datos de la escala 1:250,000 tambien se hallan disponibles por medio de un sistema computerizado disenado para manejar toda o parte de la base de datos del ITC.

Uno de los factores que fue critico en el exito del ITC fue la participacion de cientificos de todas las disciplinas conjugadas, trabajando hacia objetivos comunes establecidos en numerosas reuniones tecnicas y de direccion, sesiones de trabajo nacionales y acuerdos politicos. Los proyectos piloto de campo demostraron ser fundamentales al establecimiento de clases de capacidad, si bien la mayoria de la cartografia actual se basaba en estudios de suelos ya existentes e inventarios forestales. El ITC necesito mas de una decada para completar el trabajo a un costo aproximado de \$16.00/km . incluyendo la publicacion de mapas y el dessarrollo computerizado.

Se ha efectuado el levantamiento cartografico de numerosas areas que abarcan desde unos cuantos hasta varios miles de kilometros cuadrados por el metodo de Estudio Ecologico de Tierras (EET). El EET comprende varias disciplinas para cartografiar y clasificar las propedades basicas de los ecosistemas y registrarlas en un mapa unico. El EET consta de tres fases principales: (i) la propuesta de estudio por la que se establece un dialogo entre el patrocinador o promotor y el clasificador, tiene por objeto establecer el detalle, tiempo y alcance del estudio en relacion con las necesidades del usuario; (ii) la clasificacion ecologica de tierras, comprende trabajo de campo, interpretacion fotografica, identificacion, cartografiado y caracterizacion de los ecosistemas, y la preparacion de una base de datos orientados a las necesidades del usuario; y, (iii) evaluacion ecologica de la tierra, interpretacion de los datos para usos varios, e impactos y aplicacion de los hallazgos correspondientes en el proceso de planificacion. El EET es jerarquico y se usa generalmente a escalas de 1:25,000 hasta 1:1,000,000. Los costos estan en funcion de la escala, del area y del emplazamiento, pero el costo representativo de estudios de grandes extensiones puede oscilar desde unos dolares hasta varios multiplos de diez por kilometro cuadrado.

Actualmente, el Serie Informativa sobre el Uso de las Tierras del Norte estudia el uso de la tierra en el Yukon y en los Territorios del Noroeste, asi como en lugares de valor historico y arqueologico y areas importantes para la fauna. Una caracteristica especial de esta serie es el uso que hace de archivos, de datos publicados y del conocimiento local de habitantes y cientificos. Desde 1971 se han cartografiado dos tercios de nuestra region artica a escala 1:250,000, y a un costo de \$1.17/km^2 que incluye salarios y publicacion del mapa. Recientemente se ha anadido un reconocimiento por el metodo EET a un costo adicional de \$0.09/km^2.

Basandonos en la experiencia adquirida con estos tres metodos para efectuar el inventario de una gran extension terrestre, recomendamos un enfoque interdisciplinario para la recopilacion de informacion sobre recursos o del ambiente, dado que evita la duplicidad de costos y numerosos gastos generales, y en razon a que una estrecha asociacion de trabajo entre cientificos que abarquen varias disciplinas fomenta o da lugar a una mejor base de datos en servicio de la gestion y planificacion de recursos multiples. Y hemos llegado a la conclusion de que el exito de un estudio esta intimanente relacionado con la efectividad del dialogo entre usuarios y cientificos, el cual tiene lugar antes de efectuar la clasificacion de la tierra.

Survey Planning Model: Application for Arid Land Resource Inventories[1]

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Abstract.--The Survey Planning Model (SPM) is a series of computer programs that enable the user to make an optimal allocation of sample survey effort for a given multipurpose sample design. This program is illustrated using planning data for estimation of forage production and pinyon-juniper volume on a test site in Arizona.

INTRODUCTION

The increased and varied information needs of the wildland resource manager has made it necessary to develop inventory plans that are multipurpose in nature. For the arid land manager the inventory planning is further complicated by the large areas that must be surveyed. This has brought about the use of "higher level" sampling designs and considerable research on the "best" combination of information sources to use in large multipurpose inventories.

Proposals for dealing with the information needs of the land manager were the subjects of two recent SAF working group conferences (Frayer 1979 and Lund et al. 1978). Attention has been focused on the measurement procedures, the statistical sampling designs, and the computational procedures for specific multipurpose designs. While these aspects of multipurpose inventories are not independent of one another, the primary emphasis here will be on designs for multipurpose sampling.

Langley (1975) and Frayer et al. (1979) have described some of the procedures necessary to allocate sample effort in some multistage and multiphase designs when estimating single parameters. The basic approach is to choose the sample allocation that meets the specified precision level for the smallest possible cost (referred to as "optimum" allocation).

In multipurpose survey design, an allocation of effort that may be optimum for estimating one parameter may be relatively inefficient for estimating another. "Optimum" allocation in the multiparameter surveys is then defined to be the least-cost allocation of effort to meet the precision requirements of all parameter estimates.

If more than one sample design is contemplated, an optimum allocation is obtained for each and then, theoretically, the design that meets the objectives for the lowest overall cost is selected for use. Other considerations for the final selection are discussed below.

For any survey planning one must have some information about the population being studied and the cost and variance relationships for the sample designs contemplated. Pilot surveys and previous inventories will often supply some of this information. However, it is usually necessary to make quite a few assumptions and guesses in order to obtain a data base for planning a survey. Thus, any solution to the survey allocation problem is not without risk. Careful review of the solutions for the various alternatives represents only one of the many considerations in accepting the final design configuration.

OPTIMUM SAMPLE SIZES

To solve the multipurpose sample allocation problem, a series of computer programs were developed by the staff of the Remote Sensing Research Program (RSRP), University of California. These programs, referred to collectively as The Survey Planning Model (SPM), follow the concept initiated in the univariate case by Aldred (1971). That is, a spatially-referenced population "representation" is constructed and the sampling units defined to develop the necessary variance information required for a minimum-cost allocation

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[1]Paper presented at the Workshop "Arid Land Resource Inventories: Developing Cost-Efficient Methods," La Paz, Mexico, Nov. 30 - Dec. 6, 1980.

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using a mathematical programming algorithm.

Descriptions of the SPM have been given in previous papers by members of the RSRP staff (see citations by Wensel et al. 1979) and the general theory was presented in a PhD thesis by Titus (1978). Also, the SPM is being implemented by the USFS in Fort Collins and by BLM in Denver.

In the current version of the planning model there are three basic designs to choose from with "variations on the design" as follows:

A. Three Basic Designs
   1. Stratified - (single stage)
   2. Stratified - Two stage
   3. Stratified - Two stage - Double

B. Variations on the Design
   1. Equal or variable probabilities of selection at the first stage.
   2. Variable cluster size
   3. Alternative methods of stratification.

"Variations on the design" are actually variations on the way the population is finally represented and set up for sampling. The user may add additional sampling designs to the SPM by providing specifications and modifications as detailed by the Programmer's Manual.

The Survey Planning Model depicted in Figures 1 and 2 is actually a set of four computer programs: MCGEN, SIMULATE, CLUSTER and SUMT. MCGEN is simply an input program for SIMULATE which reads the class statistics and writes them out (binary) in a form compatible with SIMULATE. SIMULATE takes the "spatially referenced" population description and produces simulated values for each element in the

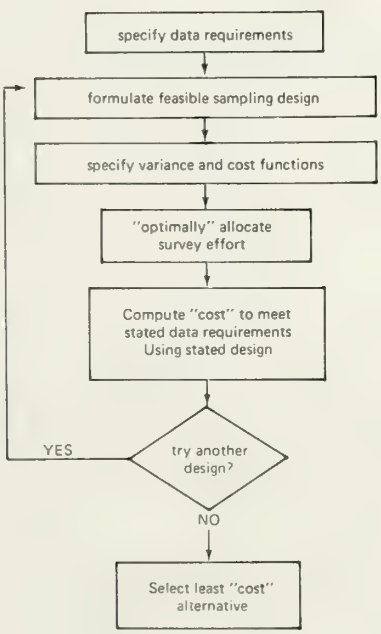

Figure 1.--Conceptual steps in the process of choosing the least cost sampling design.

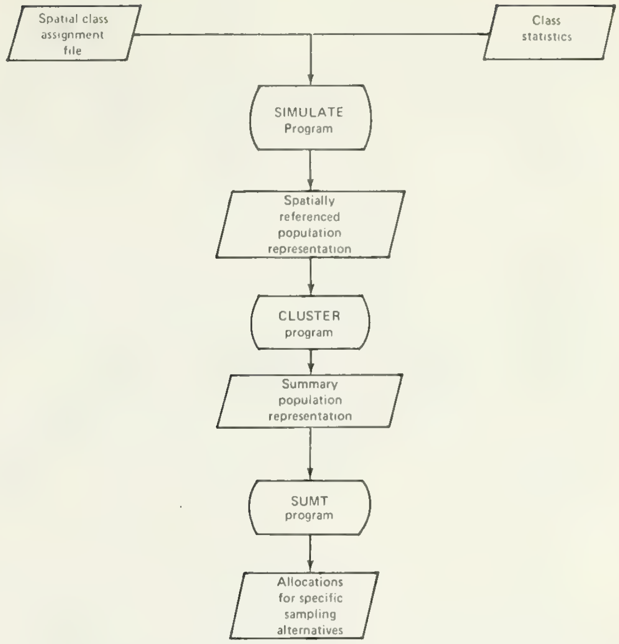

Figure 2.--The U.C. Berkeley Survey Planning Model Program Flow.

population. These values are fed into CLUSTER which then groups the elements and stratifies the population to form the specified sampling frame. SUMT performs the actual optimization according to the given design. No computations are performed by MCGEN but the functions of the other programs are discussed below. The information flow within the SPM is depicted in Figure 3.

Population Representation

As indicated above, SIMULATE produces a simulated parameter vector for each cell in the population. It requires two data input files (see figure 3). The first is a cell-by-cell spatial class assignment file (the class map) representing a cover type map for the survey area registered to some (X, Y) coordinate system. This file can be developed from digitizing strata on existing maps or from classification of digital Landsat, aircraft, and/or terrain data. The second input to SIMULATE is a set of resource parameter estimates (mean vector and covariance matrix) for each class of interest.[4] These data, referred to in Figure 3 as the "class statistics" are entered through the program MCGEN. Assuming a multivariate distribution of population elements, SIMULATE uses the class map and the class statistics to produce a spatially-referenced population of simulated resource values.

Summary Representation

The SIMULATE results are input to the program CLUSTER which constructs a sample frame by grouping

[4] A "class of interest" here may be a combination of classes in the class map file.

individual population cells together to form the primary sample units (i.e., clusters). Clusters created in this manner are assigned to strata by CLUSTER using a "plurality" assignment rule;[5] i.e., clusters are assigned to the stratum having the largest number of cells within the cluster. The number of clusters classified into each stratum is summarized for input to the optimization program SUMT (see below).

CLUSTER then produces within and between cluster covariance matrices, statistics, and probabilities of sample unit selection. Both within and between cluster covariance matrices are computed directly from the cluster structure and the specified method of probability selection (equal or variable). In current applications variable selection probabilities, if used, are defined as the area occupied by cover types of interest in a given first stage unit relative to the total area in that unit.

Sample Allocation for a Specific Design

The optimum allocation of sampling units among the sample stages and strata is done using the program SUMT, a nonlinear programming procedure developed by Mylander et al. (1971) and based upon the theory presented by Fiacco and McCormick (1968). The SUMT program contains an option

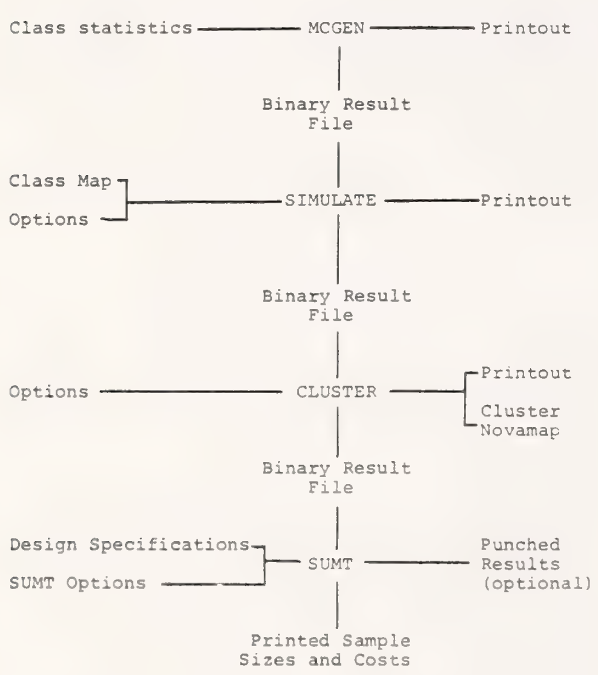

Figure 3.--SPM input and output flow.

[5]Alternatively, an option has been left to allow the user to code some other stratification procedure. This option has been used at RSRP in test runs with a cluster program which assigns the cluster to the stratum having the "most similar" mean vector.

allowing the user to select one of three sample designs (above). It uses the sample frame and statistics produced by CLUSTER along with other design characteristics such as stratum-specific correlations and cost coefficients appropriate to each sample design considered. The program selects the sample allocation that minimizes the total variable cost (TVC) subject to minimum precision and sample size constraints the levels of which are specified by the user.

RANKING ALTERNATIVE DESIGNS

After the optimum sample allocation is obtained for each alternative design, the designs can be ranked by their total variable cost (TVC). Theoretically then the design with the lowest TVC is the optimum. However, it would be short sighted to let TVC be the single deciding factor in the choice of the design to use since many other factors need to be considered.

At this point it is necessary to evaluate a number of practical considerations. These include the following:

(1) What is the risk and accuracy associated with the cost, variance, correlation, and other data used in the solution?

(2) Are there likely to be other uses that will be made of this survey that have not been specified? (There is some risk in using variable probability sampling if the sample data are likely to be used for other purposes.)

(3) What fixed costs separate the designs? These would include such things as the cost of training and equipment. (For example, one design may require additional training and/or equipment from that of another.)

(4) Which design is the most flexible to meet changing information needs?

Since the ranking of alternatives depends upon criteria particular to the specific application, this topic is not treated in any detail in the User's Manual.

APPLICATION TO ARID LANDS

SPM Example: Arizona

Since land resource inventories are often large in scale and multipurpose in nature, they can benefit from optimization using the SPM. This is particularly true since Landsat digital data can be obtained for planning as well as carrying out the inventory.

The illustration that follows draws upon the work done by Thomas and De Gloria (1978) and ESL (1978) for the Shivwits Resource Area within BLM's Arizona Strip District in northwestern Arizona. The District is situated to the north of the Lake

Mead National Recreation Area and the Grand Canyon National Park in the northwestern corner of Arizona. The Resource Area is bordered on its western edge by the Basin Range Province while the remainder of the area is within the Colorado Plateau with associated big sagebrush and grasses in the central portion and pinyon pine, juniper and sagebrush in the upper elevations. Vegetation present in smaller quantities include areas of chaparral, oak woodland and ponderosa pine. Elevations range from 1600 and 8200 feet and rainfall from about four to sixteen inches per year (BLM, 1979).

For the purpose of this example, however, only a portion of the study area was used (due to the high cost of running SIMULATE). This subarea of about 160,000 acres, consists of all of the Mainstreet and the Whiterock-Soapstone allotments the southern one-third of the Lower Hurricane allotment and the eastern one-third of the Toquer Tank allotment (BLM, 1979). This selection encompassed most of the vegetation types present in the Shivwits Resource Area -- from the desert vegetation in the east to the pinyon-juniper type in the west.

In the original study, the SPM was used to determine the sample allocation necessary to estimate cattle-usable forage biomass in the rangeland areas to within the desired precision goals. However, since no reliable ground forage biomass data were available for all sampling strata, the substitute variable vector (% cover trees, % cover shrubs, % cover grass/forbs) which could be estimated on large scale photos (LSP's) was used here instead.

Thus the problem posed in this example is to estimate the optimum number of sample units necessary to obtain estimates of percent cover of (1) trees, (2) shrubs, and (3) grass/shrubs, each within $\pm$ 20% at the 80% level of confidence. "Optimum" here is defined to be the allocation of the various types of samples that achieves the stated precision level for the lowest possible cost.

In order to effect a solution to this problem, a population "representation" was developed using Landsat and other descriptive data. Further, the performance and cost coefficients of the proposed sampling design had to be provided to the SPM.

In the original study the optimum sample allocations were computed for three sample design: (1) stratified, (2) stratified two-stage, and (3) stratified two-stage double (s2sd) sampling. The present example illustrates only the third sample design, s2sd sampling.

The Class Map. The Landsat spectral reflectance data were analyzed by the program ISOCLAS, a maximum likelihood clustering algorithm, which produced 117 classes. The resulting digital map was then combined with elevational data registered to a UTM coordinate system with cells 50 meters on a side.

Table 1. Strata descriptions

Class	SUMT Stratum (PSU's)	Description	Figures 4 & 5 Color 1
1		Creosote-Bursage (Rocky)	Pink
2		Creosote-Bursage (Sandy)	Charcoal
3		Creosote	Blue
4		Mixed Desert Shrub	Charcoal
5	1	Shrub-Grass	Magenta
6		Mtn. Shrub/Chaparral	Dark Blue
7	2	Grass-Sagebrush	Light Green
8	3	Snakeweed-Grass/Salt Shrub	Light Blue
9	4	Sagebrush/Mixed Shrub	Dark Green
10	5	PJ - Sagebrush	Red/Orange
11	6	PJ - Shrub	Yellow
12	7	PJ	White
13	-	PP - Shrub Mix	Charcoal
14	-	Shadow	Olive
15	-	Upland Desert Shrub	Red
16		Ignore	Charcoal

[1]Color copies of figures 4 & 5 are available from the authors.

The class map was then constructed by grouping the Landsat spectral classes according to (1) spectral similarity, (2) similarity in ground species composition, and (3) elevational zones. This grouping resulted in the 27 classes of the input file. These classes were further reduced to fifteen strata of interest by combining similar classes and eliminating classes which were not pertinent to the rangeland estimation objectives. Class correspondence between the 27 input classes and the 15 classes of interest was specified via option cards in SIMULATE. The final-combined class map is given in figure 4 with the strata descriptions given in Table 1.

Figure 4.--New Class Map.

Figure 5.--Cluster Class Map.

Sample Units. The 50x50 meter cells were then grouped, by the program CLUSTER, into primary sample units (PSU's or "clusters") 40 by 8 cells in size as used in the original study. Each cluster was then assigned to a stratum based upon plurality, i.e., the stratum represented by the highest number of cells was judged to be the stratum for the entire cluster. The resulting map of clusters (PSU's) is shown in figure 5.

Class Statistics. A total of 1200 large scale photo (LSP) plots were interpreted on imagery flown in 1978 with about 10-12 plots per line. The percent cover was estimated for (1) trees, (2) shrubs, and (3) grass/forbs on each plot and the data grouped by sampling strata for calculation of the mean vector and covariance matrices.

Other Inputs. Since two-stage double sampling is being considered, it was necessary to enter the expected correlations between the LSP's and the actual measurements, to be taken on the ground (forage biomass in the rangeland case). These correlations depend upon the physical relationships that exist as well as the actual field procedures used (which are not specified here). The correlations used in this illustration were established by hypothesis based upon experience and some guess work, and varied from 0.5 to 0.8 for the various variables and strata.

Also, stratum-specific cost coefficients for the stratified two-stage double sampling option were derived and made stratum-specific based upon judgement and field observations by Thomas. A complete listing of the cost and correlation data used in this illustration is available from the authors. After stratification, only 7 strata had a sufficient number of PSU's to consider. These were renumbered from 1 to 7 for convenience and their correspondence with the previous classes given in Table 2. The remaining strata had fewer than 3 PSU's assigned to them by the plurality rule.

Table 2. Sampling units by stratum.

Stratum	Class 1	PSU's
(no.)	(no.)	(no.)
1	5	7
2	7	420
3	8	222
4	9	79
5	10	151
6	11	115
7	12	13
Total		

[1]see Table 1 for descriptions.

The constraints for the SUMT calculation of the optimum number of samples are as follows:

(1) Maximum allowable error is ± 20% divided by Student's t for 80% level of confidence.

(2) The number of PSU's possible are as given in Table 2 and the maximum number of photo plots per PSU assumed to be 320 (i.e., or 1 per cell).

(3) The maximum number of ground plots is constrained by the number of photo plots selected.

(4) The minimum sample sizes are set at 2 PSU's, and 2 photo plots per 1 photo plot per PSU.

(5) Sufficient degrees of freedom must exist for regression estimation.

The Solution. The sample sizes computed by SUMT are given in Table 3. Since fractional samples cannot be taken, the rounded solution (0.1 or more rounded up) is also given. Thus, the solution calls for 31 PSU's to be selected (equal probability used here) over the 7 sampling strata. The number of photo plots per PSU varies from 2 to 12, with the largest number being taken in the grass-sagebrush stratum. In the first and seventh strata, shrub-grass and pinon-juniper, the same numbers of ground plots as photo plots are recommended.

Note also that while the rounded solution necessarily costs more, it also gives a higher level of precision than the unrounded solution. However, both are within the specified level of ± 20%.

Finally, it is important to point out that the results of a planning exercise, such as this, represent only part of the information used in inventory planning. The realism that is possible here is dependent upon how well you are able to describe the manager's objectives in quantitative terms, how well you are able to describe the population to be sampled, and how well you can model the sampling system alternatives.

Looking back over any inventory exercise - real or simulated - it is possible to point out where things should have been done differently.

Table 3. Final SUMT Solution

I. Optimum number of samples (nos.)

Stratum	Class	PSU's real	PSU's rounded	Photo Plots real	Photo Plots rounded	Ground Plots real	Ground Plots rounded
1	5	2.0	2	2.0	2	1.5	2
2	7	8.0	8	11.1	12	1.0	1
3	8	5.2	6	8.2	9	1.0	1
4	9	3.6	4	3.9	4	1.0	1
5	10	4.4	5	6.6	7	1.0	1
6	11	3.8	4	4.6	5	1.0	1
7	12	2.0	2	2.0	2	1.5	2

II. Value of the cost function
C = $6077 real sample sizes
C = $6791 integer sample sizes

III. Precision levels at solution (± 20% minimum)

	real	integer
% trees	14.7%	13.8%
% shrubs	13.0%	12.3%
% grass/forbs	20.0%	18.6%

Using the SPM, alternative strategies can be simulated at very little cost comparted to actual field inventories. In most of our applications a number of solutions are generated using alternative design inputs. These would be ranked by cost and finally, from among the highest ranked, one design chosen for implementation.

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RESUMEN

El "Survey Planning Model (SPM), ("Modelo de Planificacion de Medicion") consta de una serie de programas de computadora que permiten al usuario el hacer óptima asignación del esfuerzo necesario para un muestreo de mediciones de un diseño dado de muestreo multiple. El SPM deja el usuario escoger entre 3 diseños básicos de muestreo con variantes opcionales en los componentes del diseño. Para el diseño escogido, el modelo computará el número óptimo de muestras por su estrato y fase.

Se presenta un ejemplo de SPM usando datos de planificación para estimar la producción de forraje y el volumen de piñón-enebro en una parcela de medición en Arizona. Específicamente, la asignación de la muestra óptima se obtiene para estimar el porcentaje de cobertura de (1) árboles, (2) arbustos, y (3) gramíneas y hierbas, dentro de ± 20% con un nivel de confianza de 80%.

Intra-Cluster Correlation in Sample Design[1]

James D. Nichols[2]

Intracluster correlation (autocorrelation) is the characteristic of populations that can cause the cluster sampling approach to fail to reduce cost. Imperical data indicates the large value of autocorrelation in actual populations. Planning model runs show the effect of this high autocorrelation on sample size requirements.

INTRODUCTION

The justification for multistage sampling is to reduce the cost of data by grouping samples into clusters thus reducing travel cost. The practice of placing range inventory plots in transects and the practice of placing forest plots in 2 to 10 point clusters are common operational examples of multistage sampling. However, the samples within a cluster are not independent. In practice the value of the characteristic of interest (wood volume, available forage, etc.) can be predicted to varying degrees from the first plot visited in the cluster. The degree to which the value on other plots can be predicted from the first plot determines the amount of new information that will be obtained visiting the additional plots in the cluster.

In general the greater the plot spacing within a cluster the more information will be contributed by additional plots. However, the cost of obtaining additonal plots will increase due to the added distance between plots.

The inventory planner must trade-off four cost items when optimizing the multistage inventory:

1. reduced cost from placing plots in clusters (groups);
2. increased cost caused by the increased number of plots required when the plots are not providing independent samples when allocated in clusters;
3. decreased cost caused by the reduced number of plots when plots are spaced further apart within each cluster;
4. increased cost caused by increasing distance between plots within a cluster.

The cost associated with travel is relatively easy to visualize and model mathematically. However, the cost associated with the number of plots per cluster and the number of clusters required is more complex. The easiest model to understand on an intuitive basis is the one presented in Sampling Techniques by William G. Cochran. He expresses the variance as a function of intracluster correlation.

FORMULATION

To demonstrate the effect of intracluster correlation the field data from the National Aeronautics and Space Administration/Bureau of Land Management Application Pilot Test for vegetation inventory in Arizona was analyzed. Specifically the woodland strata for Pinyon-Juniper was used to estimate intracluster correlation as a function of plot spacing for use in comprehensive planning model.

The variance of the mean ($\bar{Y}$) for cluster sampling is calculated in terms of intracluster correlation by:

$$\mathrm{Var}(\bar{Y}) = \left(\frac{1-f}{n\ M}\right) S^2 (1+(M-1)\rho_c)$$

$$S^2 = \frac{\sum\sum\left(Y_{ij} - \bar{\bar{Y}}2\right)^2}{nM-1}$$

i=transect number
j=plot number within a transect

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[1]Paper presented at the Arid Land Resource Inventories: Developing Cost-Efficient Methods. La Paz, Mexico. November 30 - December 6, 1980.

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$$\rho_{ac} = \frac{S_b^2 - S^2}{(M-1)S^2} \text{ = intracluster correlation (autocorrelation)}$$

$$S_b^2 = \frac{\sum (Y_{ij} - \bar{Y}_i)^2}{M(n-1)} \text{ = variance of the transect means on a plot basis}$$

$$\bar{\bar{Y}} = \frac{\sum\sum Y_{ij}}{n M} \text{ = grand mean per plot}$$

$$\bar{Y}_i = \sum_{j=1}^{M} \frac{Y_{ij}}{M} \text{ = plot mean per transect}$$

The above functions were used to calculate the mean($\bar{\bar{Y}}$), variance of the plots (S^2), variance between transects (S_b^2) and the intracluster correlation (ρ_{ac}) for several groups of transects. These calculations were made using the western most plot of a 15 plot east-west transect as the base (plot #1) and one other plot from 2 through 15 as the second plot in the cluster. This provided estimates of intracluster correlation as a function of plot spacing.

If the results of this analysis are plotted for the P-J volume, Figure 1, the downward trend in intracluster correlation as a function of plot spacing can be seen.

Two isoproduction tables are included. The first, Table 1, shows the number of transects required given the autocorrelation and number of plots per transect. The second, Table 2, shows the total number of plots required, given the autocorrelation and number of plots per transect. Both tables are for ±10% allowable error, 7 times out of 10, with an expected coefficient of variation (cv) of 60%.

These tables can be used in conjunction with Figure 1 to estimate the number of transects and plots per transect required to meet the ±10% at the .7 probability. For example, if the plot spacing were kept the same as the original, the expected autocorrelation would be .58. The number of transects required for a given number of plots per line is:

# of plots	1	2	3	4	5	6
# of transects	36	29	27	26	25	24

# of plots	7	8	9	10
# of transects	24	24	24	23

There is little reduction in the number of transects required after the second plot is added.

Figure 1--Intracluster correlation versus plot spacing in meters.

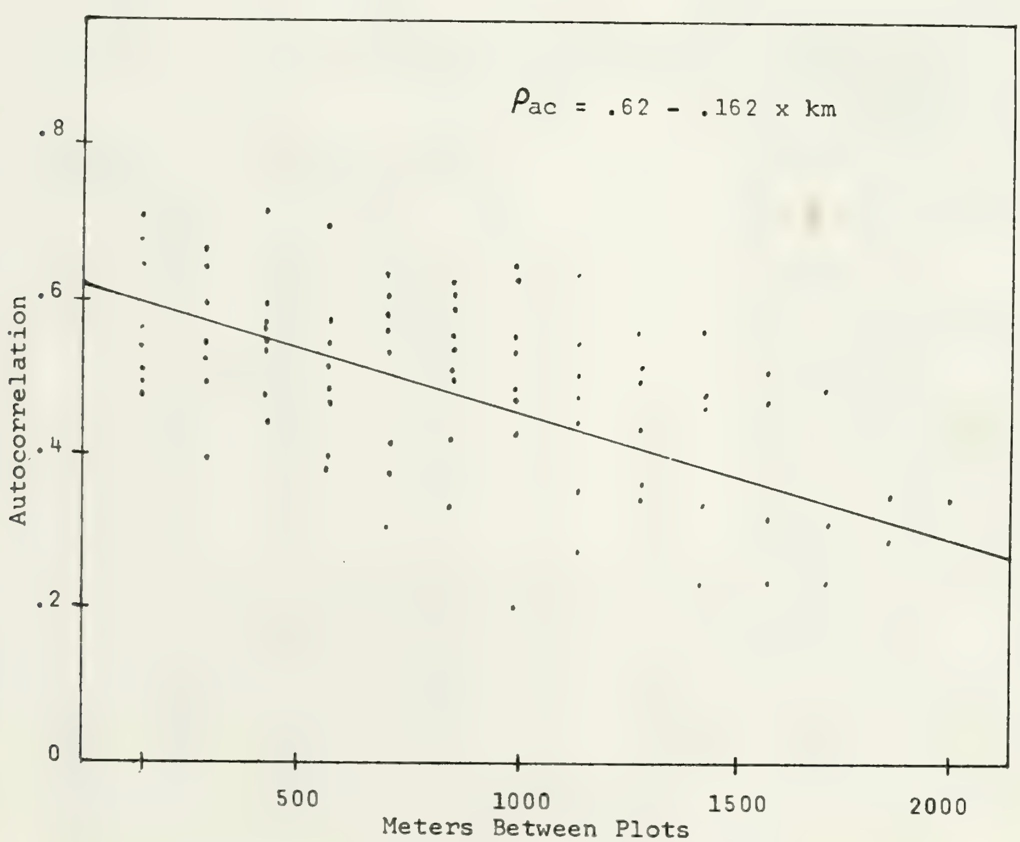

Table 1--Number of transects required (n). Isoproduction function for cluster sampling for cv = 60% and a specified allowable error (AE = ±10%) 7 times out of 10.

AUTO COR.	M=1	M=2	M=3	M=4	M=5	M=6	M=7	M=8	M=9	M=10	M=11	M=12	M=13	M=14
.05	36	19	14	11	9	8	7	6	6	6	5	5	5	5
.1	36	20	15	12	10	9	9	8	8	7	7	7	6	6
.15	36	21	16	13	12	11	10	10	9	9	9	8	8	8
.2	36	22	17	15	13	12	12	11	11	10	10	10	10	10
.25	36	23	18	16	15	14	13	13	12	12	12	12	11	11
.3	36	24	20	18	16	15	15	14	14	14	13	13	13	13
.35	36	25	21	19	18	17	16	16	16	15	15	15	15	15
.4	36	26	22	20	19	18	18	18	17	17	17	17	16	16
.45	36	27	23	22	21	20	19	19	19	19	18	18	18	18
.5	36	27	24	23	22	21	21	21	20	20	20	20	20	20
.55	36	28	26	24	23	23	23	22	22	22	22	22	21	21
.6	36	29	27	26	25	24	24	24	24	23	23	23	23	23
.65	36	30	28	27	26	26	26	25	25	25	25	25	25	25
.7	36	31	29	28	28	27	27	27	27	27	27	27	26	26
.75	36	32	30	30	29	29	29	29	28	28	28	28	28	28
.8	36	33	32	31	31	30	30	30	30	30	30	30	30	30
.85	36	34	33	32	32	32	32	32	32	32	31	31	31	31
.9	36	35	34	34	34	33	33	33	33	33	33	33	33	33
.95	36	36	35	35	35	35	35	35	35	35	35	35	35	35
1	36	36	36	36	36	36	36	36	36	36	36	36	36	36

Table 2--Number of plots required (n * M). Isoproduction table for cluster sampling for cv = 60% and a specified allowable error (AE = ±10%) 7 times out of 10.

AUTO COR.	M=1	M=2	M=3	M=4	M=5	M=6	M=7	M=8	M=9	M=10	M=11	M=12	M=13	M=14
.05	36	38	42	44	45	48	49	48	54	60	55	60	65	70
.1	36	40	45	48	50	54	63	64	72	70	77	84	78	84
.15	36	42	48	52	60	66	70	80	81	90	99	96	104	112
.2	36	44	51	60	65	72	84	88	99	100	110	120	130	140
.25	36	46	54	64	75	84	91	104	108	120	132	144	143	154
.3	36	48	60	72	80	90	105	112	126	140	143	156	169	182
.35	36	50	63	76	90	102	112	128	144	150	165	180	195	210
.4	36	52	66	80	95	108	126	144	153	170	187	204	208	224
.45	36	54	69	88	105	120	133	152	171	190	198	216	234	252
.5	36	54	72	92	110	126	147	168	180	200	220	240	260	280
.55	36	56	78	96	115	138	161	176	198	220	242	264	273	294
.6	36	58	81	104	125	144	168	192	216	230	253	276	299	322
.65	36	60	84	108	130	156	182	200	225	250	275	300	325	350
.7	36	62	87	112	140	162	189	216	243	270	297	324	338	364
.75	36	64	90	120	145	174	203	232	252	280	308	336	364	392
.8	36	66	96	124	155	180	210	240	270	300	330	360	390	420
.85	36	68	99	128	160	192	224	256	288	320	341	372	403	434
.9	36	70	102	136	170	198	231	264	297	330	363	396	429	462
.95	36	72	105	140	175	210	245	280	315	350	385	420	455	490
1	36	72	108	144	180	216	252	288	324	360	396	432	468	504

If the plot spacing is increased to 5 times the original, the expected autocorrelation is .3 and the number of transects and number of plots required is:

# of plots	1	2	3	4	5	6
# of transects	36	24	20	18	16	15

# of plots	7	8	9	10
# of transects	15	14	14	14

Given these two examples, it is easy to see the trade-off that can be made between plot spacing within a transect and the number of plots per transect when searching for an optimum allocation of effort.

However, the design of an optimum inventory is an extremely complex process which requires trade-offs or compromises amongst numerous alternatives.

This involves the distribution of the inventory effort in both a horizontal and vertical direction.

Decisions in the horizontal direction include the determination of the size of the sample plot, the shape of a sample plot, the clustering size and arrangement of sample plots and the number of clusters required at each level of data (ground, large scale photo and Landsat).

Decisions in the vertical direction include the selection amongst alternative sources of data (Landsat, small scale photo, large scale photo and ground) and the portioning of effort between the selected lines of data to achieve an optimum mix of data from the selected sources.

A planning model has been developed which utilizes cost, time and population factors to determine the optimum allocation of effort in both of these directions. The model will handle inventories based on ground only, photo stratification followed by ground sampling, photo stratification followed by large scale photo sampling with ground subsampling, and stratification followed by complete enumeration with photo sampling and ground subsampling. It will optimize plot size, number of plots per cluster, number of clusters, and the ratio of large scale photo effort to ground effort given the required inputs.

The optimization can be done by specifying either desired precision and probability level which will estimate the effort required or by specifying budget limitations which will then estimate the expected optimum effort and predict the expected precision and probability level given the fixed budget.

Given a number of inputs associated with the cost of collecting data and the characteristics of the resource to be inventoried, the model outputs estimates of optimum:

1. plot size,
2. cluster size (number of plots/cluster),
3. sample size (number of clusters),
4. distance between plots in cluster,
5. ratio of photo to ground in double sampling,
6. expected budget for each element,
7. hours required for each element.

Input requirements:

A. Cost elements:
  1. for aircraft:
    a. speed between transects,
    b. speed on transect,
    c. average time to set up transect,
    d. average ferry time from operating base to study site,
    e. maximum safe flying time,
    f. cost of photo product,
    g. format of imagery,
    h. desired stereo coverage,
    i. ground crew cost,
    j. flight crew cost,
    k. aircraft hourly rate,
    l. expected overhead rate,
    m. expected error rate in acquisition (failure rate),
  2. for ground data collection:
    a. road network classification,
    b. expected ground speed,
      i. walking to flight line,
      ii. walking between flight lines,
      iii. driving between flight lines,
    c. time from camp to general area,
    d. expected failure rate,
    e. time to measure a sample unit or item within the unit in forests,
    f. time to set up for
      i. a transect,
      ii. a plot,
    g. data entry time per plot,
      i. per sample unit,
    h. hourly rate in dollars for crew,
      i. per diem,
      ii. per expected day length,
      iii. per expected overhead rate,
  3. for photo interpretation costs:
    a. time to set up for flight line transects (PSU),
    b. time to set up for plot within transect (SSU),
    c. time to measure attributes on plot,
    d. expected useful hours/day for interpreter.

B. Population characteristics:
  1. expected stratified variance as a function of plot size,
  2. the physical size of the unit to be inventoried,

3. the expected autocorrelation as a function of plot size and spacing,
4. the expected correlation or coefficient of determination between the enumeration estimate derived from Landsat or other imagery and the photo/ground estimates and the first phase estimate from photo/ground,
5. the correlation between the estimates made from the first phase sample photography and the second phase estimates from the ground.

To determine the effect of autocorrelation and plot spacing on an operational inventory the results of the Arizona Demonstration Project were used to estimate each of the parameters necessary to run the model. The autocorrelation as a function of plot spacing was the only parameter that was varied. All other parameters were held constant at their expected value.

Autocorrelation was estimated as a function of plot spacing using the least square fit to the data in Figure 1.

$$\rho_{ac} = .62 - .000162 \times (\text{spacing in meters})$$

The simulation was run by stepping through various plot spacings, estimating sample requirements for photo and ground and estimating the total project cost giv these sample requirements. A summary of results of this simulation is shown in Table 3.

Table 3--Summary of planning model simulation for plot spacings from 60 to 3110 meters with estimated autocorrelation, photo transects, ground transects, plots per transect and total cost given a ±20% error 8 times out of 10 for a 121,460 hectare planning unit. The Landsat to photo/ground correlation was set at .53. The photo to ground correlation was set at .88.

Plot Spacing (meters)	Autocorrelation	Number of photo transects	Number of ground transects	Number of plots per transect	Total Cost
60	.61	47	6	1	3183
60	.61	36	5	2	3153
60	.61	33	4	3	3146
60	.61	31	4	4	3345
60	.61	30	4	5	3653
670	.51	47	6	1	3183
670	.51	36	4	2	3023
670	.51	30	4	3	3217
670	.51	28	4	4	3566
670	.51	26	4	5	3800
1280	.40	47	6	1	3183
1280	.40	33	4	2	3036
1280	.40	29	3	3	3024
1280	.40	26	3	4	3253
1280	.40	24	3	5	3582
1890	.30	47	6	1	3182
1890	.30	31	4	2	3067
1890	.30	25	3	3	3030
1890	.30	22	3	4	3384
1890	.30	20	3	5	3646
2500	.20	47	6	1	3183
2500	.20	29	3	2	2719
2500	.20	22	3	3	3057
2500	.20	19	2	4	2768
2500	.20	17	2	5	3071
3110	.09	47	6	1	3183
3110	.09	26	3	2	2710
3110	.09	20	2	3	2584
3110	.09	16	2	4	2871
3110	.09	13	2	5	2962

Table 3 clearly shows that increasing the number of plots per transect has very little effect on the cost of meeting the ± 20% at the .8 probability given the high autocorrelation at the closer plot spacing. At the wide plot spacing (3110 meters) there is a significant savings. However, it is questionable whether plots seperated by 3000 meters are really clusters.

SUMMARY

With the high autocorrelation found in three populations, Pinyon-Juniper volume in Arizona, Ponderosa Pine volume in Arizona and Big Sage percent cover in Idaho, it is unlikely that transects with close spacings and a large number of plots per transect are cost effective. Transects with 2 or 3 plots at moderate spacings are probably nearly optimum. Transects with 10 to 20 plots contain much redundant data and provide very little information beyond the second plot.

Optimizing the sample design for each project has the potential of saving time and money.

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RESUMEN

La correlación intragrupal (autocorrelación) es la característica de las poblaciones que podría hacer que el sistema de muestreo grupal no reduzca el costo. La data empírica indica el alto valor de la autocorrelación en poblaciones reales. Ensayos con el modelo planificado muestran el efecto de esta alta correlación en los requisitos de tamaño de la muestra.

Planning the SCS National Resources Inventory[1]

J. Jeffery Goebel and Keith O. Schmude[2]

This paper discusses the data needs, data collection methods, sampling schemes, the quality control, data reliability, and monitoring activities associated with the National Resources Inventory, 1982. Also highlighted are previous Soil Conservation Service resource inventories.

INTRODUCTION

The collection and the use of natural resource data have long been cornerstones of the Soil Conservation Service (SCS), an agency of the United States Department of Agriculture (USDA). SCS programs have collected data on both a complete mapping and a sample basis. For example, soil surveys form the basis for much SCS local planning work and are types of resource data that have been in existence for many years. The Conservation Needs Inventories of 1958 and 1967 are two well-known and well-used sources of sample data. This paper discusses SCS resource data collection, giving particular emphasis to the planning and goals of the National Resources Inventories of 1977 and 1982.

RESOURCE DATA NEEDS AND USES

The need for additional resource data has been realized ever since the completion of the 1967 Conservation Needs Inventory (CNI). The land use and soils data have been used extensively by individuals both within and outside the federal government. However, as the 1970's progressed, there were increasing demands for current and more detailed data. SCS and USDA needed these data to respond to numerous requests, including: i) requests from the U.S. Senate Committee on Agriculture, Nutrition, and Forestry for oversight information; ii) questions related to Government Accounting Office audits of conservation practices; iii) recommendations of the Task Force on Future Directions of SCS; iv) responses to the Task Force on Adequacy of Conservation Systems on Cropland. Several laws have recognized the needs for additional data and subsequent analyses. The Rural Development Act of 1972 required a report on the status, condition, and trend of land and water resources in the United States. The Soil and Water Resources Conservation Act (RCA) of 1977 was enacted in light of expected increasing demands on basic natural resources. It is a companion measure to the Forest and Rangeland Renewable Resources Planning Act (RPA) of 1974 and directed the Secretary of Agriculture to: 1) appraise continuously the soil, water, and related resources on nonfederal U.S. lands; ii) develop a program for furthering the conservation, protection, and enhancement of these resources; iii) make a 1980 report to Congress and the public; iv) provide annual evaluation reports; v) repeat the process in 1985. The Surface Mining Reclamation and Enforcement Provisions of 1977 stipulate that prime farmland must be identified and provisions made for its reclamation before new mining activities may proceed.

The 1977 RCA and the National Resources Inventories (NRIs) are closely related. Even though the 1977 NRI was designed and initiated before passage of the 1977 RCA, the 1980 RCA Report relies on many of the estimates derived from the 1977 inventory. On the other hand, the 1982 NRI has been designed and scheduled with the mandated 1985 RCA Report in mind, even though there will certainly be a multitude of other users.

When considering the planning of the NRIs, it is advantageous to consider the use of natural and related resource data in SCS. One representation of this process is depicted in Figure 1. SCS data collection methods depend upon many factors, including budgetary constraints, time restraints, specific needs, legislation, etc. This paper concentrates on statistically-designed inventories that are national in coverage, namely the Conservation Needs Inventories of 1958 and 1967, the 1975 SCS Potential Cropland Study, and the 1977 and 1982 NRIs.

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[1] Paper presented at the Arid Land Resource Inventories' Workshop [LaPaz, Mexico, December 1-5, 1980].

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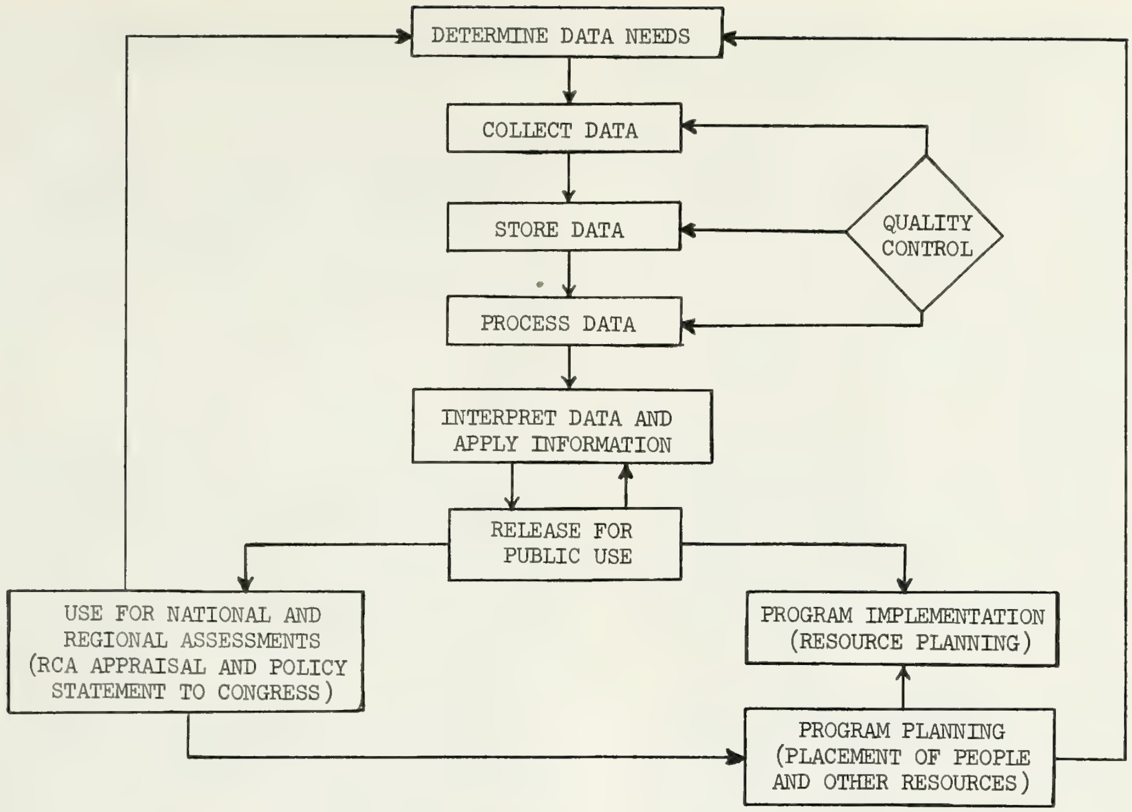

Figure 1.--Use of resource data in SCS.

THE 1958 CONSERVATION NEEDS INVENTORY

The 1958 CNI, formally entitled The National Inventory of Soil and Water Conservation Needs, employed a stratified random area sample developed by the Statistical Laboratories at Iowa State University and Cornell University, in cooperation with the SCS and seven other federal agencies. The objective of this inventory was pointed out by then Secretary of Agriculture Ezra Taft Benson in the foreword to USDA (1957) Bulletin 40-5759: "... Our resources are not, however, inexhaustible. They must be cared for and used wisely that their productiveness will be continuing. To assure their wise use we need basic facts about the physical problems of conservation -- their magnitude and relative urgency..." Later in the bulletin, conservation is defined: "Soil, water, forest, and range conservation is the protection, use, maintenance, and improvement of these resources to best serve both private and public interest in providing adequate food, fiber, forest products, recreation, and wildlife resources now and in the future." Even though the 1958 CNI was agriculturally oriented, these two excerpts of nearly 25 years ago could serve as a foreword in explaining the need to consider the items that are of concern at this 1980 Arid Land Resource Inventories Workshop.

Data collection for the 1958 CNI entailed mapping soils and land use on the statistically selected sample areas. The sampling methods are described in detail by Taylor (1962). The 1958 CNI was approximately a two percent sample of the United States' nonfederal lands. The sampling units were: i) 100-acre square areas of land, for the 13 northeastern states; ii) 40-acre squares, for many irrigated portions of western states; iii) 640-acre square areas, for some of the homogeneous regions of the western states containing large areas of range, forest, or barren land; and iv) 160-acre units, for all remaining areas. The 40-acre, 160-acre, and 640-acre units were used because of their convenience relative to the public land survey system that subdivides the land in much of the U.S. into nominal one mile squares, called "sections" (and 36 sections are aggregated into six mile squares, called "townships"). The 40-acre and 640-acre units were used in regions that were unduly heterogeneous or homogeneous, respectively. The use of subdivisions of sections makes an ideal frame of reference for drawing the sample, since these legal boundaries are nearly always indicated on detailed county highway maps. Also, for certain regions of the country, section boundaries are easily identified in the field.

THE 1967 CONSERVATION NEEDS INVENTORY

The National Inventory of Soil and Water Conservation Needs (CNI) of 1967 was a joint venture of eight U.S. Department of Agriculture agencies and the U.S. Department of Interior's Bureau of Indian Affairs to update and make current the 1958 CNI data, with the Soil Conservation Service assuming the leadership responsibilities. The 1967 sample units were specific point locations within the 1958 CNI sample areas. The 1958 CNI sample units came to be referred to then as PSUs (primary sampling units), since the points within PSUs are then secondary sampling units. The sample area patterns in all counties were reexamined before the 1967 inventory.

The specific sample points were located by using a plastic template and an aerial photograph that contained a soils map of the sample area. Instructions were given in the USDA's (1966) handbook for the 1967 CNI. There were typically 34 to 38 sample points marked on a 160-acre PSU, depending upon the orientation of the template. Soil type, land use, and conservation treatment needs were determined for each point.

The 1967 CNI point sampling method was preferred over the 1958 procedure because it was simpler to use in the field and resulted in data that were easy to process in the office. The subsampling within primary units results in less costly fieldwork but a small loss in precision, estimated by Strand and Huang (1973) to be 10 to 15 percent.

THE 1975 POTENTIAL CROPLAND STUDY

During the early 1970's there was much discussion about the availability of land that was not being cropped but was readily convertible to cropland. Data on the potential for new cropland and on current land use were needed by USDA to accurately respond to the numerous inquiries being made by Congress and many others. The 1967 CNI had furnished estimates of rural land with a noncropland use and soils having few agricultural limitations. But what portion of these lands actually had potential for conversion to cropland? And what were the problems that would be encountered during conversion? During 1975 the Statistical Laboratory at Iowa State University cooperated with SCS and the Economics Research Service of USDA in designing a national inventory that would help answer these questions.

The sample sites used for the 1975 Potential Cropland Study were a subset of the 1967 CNI locations. Samples were located in 506 counties, within which were selected 5,300 of the CNI PSUs. Within each selected PSU, only one fourth of the 1967 CNI sample points were revisited. Each selected county was given roughly the same number of sample points, in order to equalize the work load upon SCS field personnel. The allocation of sample counties per state was based upon: i) number of counties in the state; ii) size of the state; and iii) estimated amount of cropland within the state in 1967. The data items recorded for each sample point were: i) soil type; ii) 1967 land use; iii) 1975 land use; iv) whether prime farmland; v) types of problems that would significantly inhibit development for cropland; vi) type of development necessary for conversion to cropland; and vii) the potential for conversion to cropland within the next 10 to 15 years. The data collected during the 1975 study were aggregated on a national and farm production region basis.

THE 1977 NATIONAL RESOURCES INVENTORY

The 1977 National Resources Inventory involved SCS field personnel visiting 70,000 of the CNI sample plots and examining three points per PSU (two points in 40-acre PSUs). A Graeco-Latin Square idea was employed in the randomization process to spread the three points throughout the sample plot. Funds available for this study, along with a very tight time schedule, dictated a sampling scheme that allowed for state-reliable data. This study was initiated, designed, and carried out within the calendar year 1977. This highlights again an aspect of SCS resource inventories that is quite useful when using the data to make inferences about the status of various resources -- that the data are all current for a given point in time and are not an aggregation of several (possibly quite different) years. This is facilitated certainly by the system of Area and District Offices maintained by SCS.

As discussed earlier, the 1977 NRI was conducted by SCS as a step toward providing more comprehensive data on soil erosion and to help answer many other resource questions. Data collected in 1977 include: i) items historically inventoried by SCS -- soil capability, land use, and conservation treatment needs; ii) potential cropland data; iii) prime farmland availability; iv) data needed to calculate estimates of water (sheet and rill) and wind erosion; and v) other resource items, such as wetland types 3-20 and flood-prone areas. Special procedures used to improve the quality of the land use statistics were: i) the collection in early 1977 of county base data; and ii) the collection of sample data on both an area and a point basis. These activities are also an integral part of the 1982 NRI. The collection of county base data was a census type effort to establish the base acreages for each county -- total surface area, Census water (water bodies greater than 40 acres and streams wider than one-eighth mile), Federal land, urban and built-up land, and rural transportation acreages.

A statistical quality evaluation of the 1977 NRI, conducted by SCS, consisted of revisiting 3 percent of the sample plots. State Office personnel examined the designated samples and completed new worksheets. No significant differences were

found when 16 acreage estimates and 16 estimated erosion rates were statistically compared at the national level.

Phase II of this NRI was conducted in 1978-79 under the direction of SCS sedimentation geologists and engineers. Data were collected relating to those sources of erosion not considered in the first phase, namely streambanks, gullies, areas disturbed by construction activity, and roads and roadsides.

DATA NEEDS ADDRESSED BY THE 1982 NATIONAL RESOURCE INVENTORY

Data collection, processing, and interpretation are costly efforts that require careful planning in order to obtain the most for the dollars being expended. The kinds of data collected during the 1982 NRI have been determined by a combination of factors. It was important to build on past SCS inventories, wherever possible, to monitor changes and trends in resources. It was also important to include resource elements identified during the RCA process, by the public and government agencies, as being of major concern. The 1982 NRI was designed on the basis of this RCA information needs effort and is, consequently, more comprehensive than previous SCS resource inventories which were strictly agriculturally oriented.

Many different interpretive combinations of soil, water, and related resources can be generated from the resource elements identified by the 1982 NRI. The major resource elements of the inventory that have been identified as significant to resource concerns and in helping formulate SCS program direction are:

--prime farmland	--land capability classes
--irrigation	--water bodies and streams
--windbreaks	--critical eroding areas
--land cover	--saline and alkali areas
--use of land	--potential cropland
--cropping history	--conservation on the land
--erosion by water	--conservation treatment needs
--erosion by wind	--riparian vegetation
--flood prone areas	--wildlife habitat diversity
--wetlands	--pastureland condition
--range condition	--other vegetation data

Further soils related items will be available via linkage with the computerized SCS Soils-5 file, an extensive computerized soils data base. This provides a means of matching the NRI data elements to a wide selection of soil interpretations, e.g., suitability for sanitary facilities or building site development.

Several of the above data elements are of special interest to those concerned with arid lands. Information will be provided on windbreaks, irrigation, water supply, land use and cover, arid soils, saline and alkali areas, wind erosion, riparian areas, potential for cropland, wildlife habitat diversity, range condition, percent woody cover, apparent trend in rangeland condition, and level of grazing. These data will provide valuable information on how arid lands are being used and managed, what soil types and land use potentials are present, whether rangeland conditions are improving or deteriorating, and what conservation practices are needed.

DATA COLLECTION METHODS

The first goal of the data collection is to have base statistics that are compatible with the definitions used by SCS, are reconcilable with figures used by other agencies, and reflect the base year (1982) conditions. The collection of the county base data for the 1977 NRI was mentioned previously. These census-type data will be carefully monitored for the 1982 NRI. The rural nonfederal land acreage thus developed serves as the base for estimating and classifying the various land use areas via sample data.

When studying natural resources there are various sampling unit types to consider, e.g., areas, linear transects, points, and volumes; the optimal choice depends upon the characteristic under consideration. The NRI scheme employs both area and point sampling as a compromise between optimality and practicality. Most land use categories are estimated using the point data since these acreages can then be easily cross-classified by the many other resource characteristics being studied, e.g., soil classification, wetland status, erosion estimates, etc. This cross-classification ability can be virtually lost if other methods are used. Data are gathered on a PSU (area) basis for two main reasons: i) estimates derived strictly from points may not be reliable enough, e.g., for resources occurring as small areas or having linear features such as small streams; and ii) to aid the field worker in properly completing the data gathering forms.

Two aspects of data collection relative to an SCS resource inventory need to be stressed. Soil surveys furnish readily available soils information for many sample locations, assist in making technical judgments, and aid in locating the samples on the ground. The second aspect is the network of State, Area, and Field Offices that place SCS personnel in nearly every U.S. county.

Present NRI data collection activities do not depend upon photo interpretation and remote sensing techniques. This certainly will change as the state of the art and the availability of materials covering a condensed time period improve. Even then it will not be a simple task for SCS personnel to make the technical judgments needed when collecting NRI data.

SAMPLING SCHEME

The basic sample design for the 1982 NRI employs both stratification and a two-stage selection process in determining the sample locations. For administrative purposes and to facilitate sample selection, each of the 3,300 plus counties in the United States serves as the base region for sample selection. The stratification process includes geographic stratification for all counties. Further stratification relative to broad resource regions is utilized in a number of counties, particularly in those parts of the country where irrigation strongly affects land use and related resource patterns. The two-stage selection procedure is similar to that used for the 1967 CNI and the 1977 NRI. The first-stage units are areas of land selected randomly within the strata, and the second-stage units are specific point locations within the selected first-stage units (PSUs, or primary sampling units). The points are selected using the 1977 NRI procedure.

The basic PSU selection procedure for counties in 35 of the 50 states is quite similar to the 1958 CNI procedure. The basic geographic stratification procedure is best illustrated by considering a regular township of 36 sections divided into six rows, each containing six sections. Three geographical strata are formed from this township: i) stratum one is the top (or northern) two rows, consisting of sections 1 to 12; ii) a second stratum contains sections 13 through 24; and iii) the third stratum contains the bottom two rows, sections 25 through 36. Each stratum then contains 48 quarter-sections (160-acre square areas), from which a predetermined number of PSUs are randomly selected. A common sampling rate for the 1957 and 1967 CNIs was the selection of one unit from each 48, i.e., a 2% rate. A number of counties have a 4% sample for the 1982 NRI, which means two PSUs are selected per stratum. Smaller sampling rates can be obtained by combining the appropriate number of blocks of sections. The sections within a county that are not part of a complete township are grouped into strata in a convenient, systematic fashion.

This stratification procedure can be extended to counties and states which are not sectionalized relative to the public land survey system. A pseudo-township pattern is typically imposed upon the county, i.e., grid lines are established at 6-mile intervals. The resulting blocks of 36 square-mile areas are then treated like townships, and half-mile square areas are selected as PSUs. Another modification involves stratifying both geographically and relative to additional relevant factors. These adjustments occur mainly in the arid regions of the western U.S., where present and potential irrigated regions are formed into strata containing 12 sections (of similar land). Dry cropland areas are also grouped together. Occasionally, ownership patterns are incorporated into the stratification pattern. The main objective in this additional stratification is to more optimally allocate the sample, i.e., create strata that are more homogeneous relative to the resource items of interest and make sampling denser or sparser depending upon the stratum type.

Geographical stratification based on latitude and longitude is being employed for the 1982 NRI for counties within the 13 northeastern states. Strata are rectangular subdivisions of the earth's surface, being two minutes of latitude by four minutes of longitude in size. The PSUs for these counties are areas 20 seconds of latitude by 30 seconds of longitude in size. The PSUs selected in this manner are not quite square and range in size from 96 acres in northern Maine to 113 acres in southern Virginia. Three specific points are selected within these PSUs in a manner similar to that used for 160-acre PSUs, taking into consideration the varying dimensions.

An alternative sample design, based upon the Universal Transverse Mercator (UTM) grid system, is presently being used in only one state, Louisiana. This scheme employs randomization rather than the more traditional two-dimensional aligned systematic concept; a Graeco-Latin square idea incorporates balance, as discussed further by Goebel and Schmude (1980). The system uses both areas and specific point locations as sampling units. Each 4-kilometer square serves as a stratum. The area samples are 0.5 kilometer squares (25 hectares, or 61.8 acres) selected within these strata; then one specific point is chosen within each selected area. Data are collected on both the specified point and the 61.8-acre area. This sampling design is somewhat inefficient relative to field worker costs, since it does not cluster the points and uses smaller areas. An advantage is that computerized geographical display of the data is more straightforward than under other sampling designs.

Alternative sampling schemes are being considered for heavily forested nonfederal areas. A method incorporating several stages of stratification constructed through aerial photography and satellite imagery is being developed for Alaska. Pilot projects that are cooperative efforts with the Forest Service are being conducted in portions of Maine and California.

QUALITY CONTROL

Quality control is necessary to meet the need for an accurate and credible National Resources Inventory. For the 1982 NRI, quality control is the primary responsibility of the SCS State Offices with local input from Area Offices working with the Field Offices. The four SCS Technical Service Centers (TSCs) have a major role in providing leadership and guidance to the overall quality control effort in their region. Quality control for the NRI is a continuous integral part of the overall supervision, training, and management process. It also involves field and other checks of a minimum of a three percent subsample of the PSUs or five

PSUs for each county, whichever is greater. Higher rates are checked where necessary. This subsample of completed PSU worksheets is checked by technically qualified people other than the original recorder.

All worksheets are checked and edited in Area and State Offices prior to their transmittal to the Statistical Laboratory at Iowa State University. Special guidelines have been prepared to check the data for compatibility and reasonability. This involves both visual scanning and special computer manipulation of the data by the Statistical Laboratory. Examples of such checks are to compare prime farmland with land capability class, or to check soil loss levels on areas designated as adequately treated. The data worksheets are visually scanned prior to data entry, in an effort to uncover obvious deviations from the instructions. Computerized compatibility checks are made progressively as the data are processed. Where possible, computerized printouts of the data are visually scanned for unusual data, preferably by someone familiar with both the geographic area and the inventory procedure.

SCHEDULING AND MONITORING

Previous SCS resource inventories were designed so that the major data collection efforts were accomplished in a single year. By contrast, data collection for the 1982 NRI will span up to three years, due to its increased scope. Hence, careful scheduling is required to complete an inventory that best represents 1982 conditions. To accomplish this goal considerations must be given to monitoring the following: i) the county base data collected in early 1977; ii) the 1977 NRI data; iii) data collected during 1980 and 1981 for the 1982 NRI; iv) data collected from 1977 through 1980 for purposes other than the 1982 NRI, e.g., for county-level use or for River Basin planning. It is expected that future inventories will build upon the 1982 NRI; this will include monitoring 1982 data as well as possibly expanding the scope of the study.

RELIABILITY OF THE DATA

A question associated with the collection of natural resource data is "How reliable are the data?" The SCS resource inventories discussed in previous sections have all had different reliability goals. The CNIs of 1958 and 1967 were aimed at collecting county-level data; the 1975 Potential Cropland Study produced estimates reliable for analysis by Crop Production Regions (aggregations of several states); and the 1977 NRI data are being used at the state level. In a general sense this means that analyses can be made at the specified geographical level as long as the data are not split into unreasonably small categories. The original SCS plans were to make the 1982 NRI a county-level study, but budgetary restraints have dictated that the 1982 data will be reliable only at a multicounty level, i.e., the sampling density will generally be such that data will be aggregated by areas smaller than a state but larger than individual counties. This multicounty-level design allows estimation by Land Resource Area (LRA), SCS Administrative Area, Water Resources Council Aggregated Subarea (ASA), and aggregations of hydrologic units and other physiographic subdivisions. The accuracy of the data can be analyzed further by considering specific examples; since many thousands of estimates are calculated for each inventory, a complete enumeration is not feasible. Examples of estimated coefficients of variation for the various inventories are given by Taylor (1962), Strand and Huang (1973), Eaton (1974), Goebel and Huang (1980), and Goebel and Schmude (1980).

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RESUMEN

Este trabajo expone las necesidades para data, métodos para recolectar data, planes para muestreo, el control de calidad, confiabilifad de la data, y actividades de supervisión associadas con el Inventario de Recursos Nacionales de 1982. Además se discuten brevemente previos inventarios de recursos del Servicio de Conservación de Suelos.

Phytoecological Surveys for Land Use Planning and Agricultural Development: 25 Years of Experience in the Arid Zones of Africa[1]

Henri N. Le Houe'rou[2]

INTRODUCTION

The present paper is based on work carried out or supervised by the author in the arid zones of Africa, North and South of the Sahara. It includes:

--Inventory of vegetation and environmental conditions over some 10 million km^2 in Tunisia, Libya, Algeria, Morocco, Mali, Niger, Somalia, and Ethiopia.

--Phytoecological mapping at various scales (1/10,000 to 1/1,000,000) mostly at intermediate scale (1,50,000 to 1/500,000) over some 25 million hectares in Tunisia, Libya, Algeria, Mali, and Ethiopia.

--Mapping of actual and potential land use.

--Evaluation of land capability for agriculture: Crops, range and forestry.

--Agricultural Development planning (as advisor).

This work was carried out under the aegeis and financial support of various organizations and agencies, essentially:

- --National Scientific Research Council (CHRS/CEPE), Paris/Montpellier, France
- --FAO, Food and Agriculture Organization of the U.N.
- --World Food Program of the U.N.
- --ILCA, International Livestock Centre for Africa.
- --Some public or private research or development organizations or universities.

It resulted in over 100 publications and reports, many published maps, and three academic dissertations in geology, botany and ecology.

SELECTION OF A METHODOLOGY

There are many ways and methods of studying vegetation, according to the aim which is pursued; such a study can be purely theoretical or entirely practical; it may also take place at various levels of perception according to the precision which is required. Some usual methods of vegetation surveys are:

--Phytogeography or Geobotany that aims at describing and explaining the main vegetation types at the world, continental, country or region levels of perception.

--Floristic geography which studies the distribution of individual species or taxa at various levels (world, continent, country, region). This may concern present day distribution or historical, or geological, hence again three different levels of perception in time.

--Phenology which is the study of changes in physiological stages as related to seasonal changes in weather or climate.

--Phytosociological studies are concerned with description, definition and mapping of plant associations, and is essentially based on floristic criteria, more or less linked to environmental conditions. This, again, refers to various schools:

The Zuricho-Montpellieran School of Braun-Blanquet, sometimes called Sigmatist.

The Scandinavian School of Uppsala of Durietz and others.

The Dutch School of DeVries; and so on and so forth.

--Vegetation dynamics which consist in the study of changes in vegetation over time, as a function of changing ecological conditions such as land use management, intensity of utilization, erosion, etc.

--Study of ecosystems and their functioning energy flows, turnovers, food chains, etc. A type of study particularly well documented in Northern Africa.

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[1] Paper presented at the Arid Lands Resource Inventories Workshop, Nov. 30-Dec. 6, 1980, La Paz, Mexico.

[2] FAO Consultant, Dept. of Renewable Natural Resources, Autonomous Agricultural University Antonio Narro, Saltillo, Coahuila, Mexico.

--Phytoecological studies which address themselves to the description, definition and explanation of plant communities in their environment; this is also called causative phytosociology. It differs essentially from floristic phytosociology in the fact that, in the latter, almost only floristic criteria are taken into consideration, while in the former ecological conditions are given equal emphasis as botanical composition and structure.

All these methods have different aims, use different techniques, and are concerned with various levels of perception both in space and time.

Here I shall address myself to phytoecology only, because this is the method that proved to be the best suited for surveys aimed at actual land use planning and agricultural development, mostly because of its in-depth analysis of both environmental conditions and vegetation (be it natural vegetation, weed communities, pyospheric communities).

The phytoecological method is essentially based on the notion of "ecological groups" (Duvigneaud, 1948; Ellenberg, 1952; Le Houe'rou, 1955, 1959; Ionesco, 1956; Gounot, 1958, 1959) which developed in western Europe and Northern Africa in the 1950's.

An ecological group is a community of plants that grow together in a given site under well defined ecological conditions. These ecological conditions are what we call the "active variables" in the environment concerned. These variables may be lumped in three main categories: climatic, edaphic, anthropozoic.

The main climatic variables affecting plant growth and communities composition in arid zones are:

Precipitation	Amount Distribution Variability
Temperatures	Mean monthly minima Mean monthly maxima
Potential Evapotranspiration	Amount Distribution Variability
Relative humidity	

and the gradients of variations of these variables with altitude and exposure.

Other variables may be locally important such as wind, hail, frost hazards during the growing season etc.

The mean edaphic variables (I do not mean pedological variables) are the same as those used in crop ecology, especially in agrology: availability of water and nutrients, i.e., water and mineral budgets in the soil. The water budget, however, is not directly and readily accessible and measurable without time consuming observations throughout seasons. One has, therefore, to evaluate it through indirect permanent criteria, as used in descriptive agrology and morphological pedology, that can be punctually measured at any moment in time.

These are essentially:

--Texture of the surface horizons which command soil permeability and therefore potential intake.

--Structure which also regulates soil permeability, porosity, apparent density and availability of oxygen.

--Soil depth which determines the potential accumulation of water and nutrients.

--Topographic situation (macro, meso and micro) which influences runoff or run-in.

--Slope which affects runoff, erosion, tillage feasibility and so forth.

--Exposure which dominates the micro-climate and basically the energy budget, and therefore local temperatures and local potential evapotranspiration.

--Presence or absence of rocks and stones which may be a limiting factor for tillage and cropping.

--Impede drainage which affects in particular the level of investments before agricultural development is actually undertaken.

Availability in geobiogene chemical elements depends on pH, exchange capacity, cathionic saturation rate, soil content in P, K, N, Ca, S, Mg, Na and sometimes other macro or micro (trace) elements, or often in arid zones, the presence of more or less toxic salts such as NaCl, Co_3Na_2, SO_4Ca, SO_4Mg, etc.

Anthropozoic variables are essentially the type and intensity of use by man and animals, mostly livestock: Forest Exploitation, Range Exploitation, Crop Farming, Mixed Exploitation (multiple use). Obviously, each of those must be subdivided into subtypes and according to intensity of utilization for instance, commercial irrigated farming versus shifting cultivation.

INVENTORY

The basis for phytoecological survey is the site investigation (Releve', Relevamiento). This releve consists in the notation, in sites selected for their homogeneity and representativity of the following elements.

1. Vegetation structure both vertical and horizontal (vertical in layers of various heights; horizontal in various repetitive and alternating combinations, usually with contiguous distribution in case of mosaics of two or more interdependent elements such as hillocks or termite mounts in their surrounding community or sciaphytic communities, etc.).

2. Exhaustive taxonomic list of the plants present on the site, and their biological type, by structural unit with quantified indexes for density (number of individuals per unit area) and plant cover (canopy) in percent.

3. Standing phytomass and estimated production for the main species (actual or potential).

4. Detailed description of the site and of its surrounding landscape, especially: altitude, slope, exposure, topographic and gemorphologic situations (macro, meso and microrelief), geology, especially structure and petrography, architecture of the landscape and land use, impacts of animals and man.

5. Climatic conditions, and recent weather conditions (current and past growing seasons).

6. Detailed morphological description of the soil and subsoil, to at least 2 m of depth (and more when needed), with sampling of the various horizons for chemical and physical analysis.

7. Particular conditions such as erosion (type and degree), sedimentation, presence of a water table or of an impeded drainage, presence of toxic salts, periodical flooding, etc.

The selection of investigation sites is the capital decision in the whole process and must be done with great care, for instance, by stratified sampling using aerial photos or satellite images, soils and geological maps, etc. The criteria for site selection are primarily:

- --Homogeneity of vegetation and environmental conditions including human and animal impacts.
- --The representative nature of the site in the landscape of the area under study. Usually

Usually sites are selected by stratified sampling on aerial photos (random sampling is too time consuming, too costly since it would require many more samples). This procedure ensures a homogeneous and representative sampling. The statistical analysis of site investigations or "releves" allows for setting up correlations between structure and botanical composition of vegetation on the one hand and environmental variables on the other; hence the definition of ecological groups.

Then, on the basis of ecological groups, are defined the vegetational units, and the classification of these units in a taxonomic framework identical to the one used in floristical phytosociology such as classes, orders, alliances, associations, sub-associations, variants, facies, and phases. Each community is thus a defined combination of ecological groups which ordinates in a quantified way and may be shown in a framework or matrix identical to Mendelejeff's table of periodical classification of the chemical elements. This matrix is called an "Ecogramme." The ecogramme may be used at various levels such as for the definition of local plant communities through ecological groups, or for the regional classification of plant communities.

The statistic interpretation of the releve's may be carried out in various ways: the simplest being the phytosociological table as used by Braun-Blanquet and other Sigmatists, or through more quantified means such as the Differential Analysis of Czekanovsky, or more sophisticated mathematical tools such as Benzecri's Factorial Analysis of Correspondences, using computerized data for Multivariate Analysis. These quantitative methods have also their weakness; they are not very sensitive since usually based only on presence/absence. Once the inventory is done and the ecological groups and plant communities are defined by a double iterative process of analysis and synthesis, one may undertake.

MAPPING

Mapping is based on

1. Photointerpretation at various scales (1/10,000 to 1/100,000).

2. Ground control of photointerpretation which may lead to some further inventorial investigations on overlooked communities. Density of control sampling naturally depends of the precision required. In many cases, all the zones delineated on the photos are visited and checked on the ground.

3. Elaboration of thematic maps. These maps are basically: land use maps; phytoecological maps; land capability maps for crops, range and forest and others used where-ever applicable.

The land use map indicates the type of land use, the intensity of their use, the type of management, the nature of crops, etc. The phytoecological map indicates and delineates plant communities and the main ecologically active or causative variables of climate, soil and human impact.

The land capability map gives for each area delineated oan the phytoecological map the alternative potential uses with their probable level of production at three various technical levels of exploitation: optimum, fiar, and poor. The evaluation of land capability includes naturally agriculture, forestry and animal production (essentially, range potential, in the latter case, possibility or not of oversowing, etc.). It must be based on all information available at field level (experiments, surveys, farmers' experience, statistics of production, etc.). It may require further field investigations on the potential yields of a given crop or re-afforestation species or sown pastures, etc. This phase must be carried out by interdisciplinary teams including: ecologists, agronomists, animal production specialists, range scientists, foresters, agro-economists and socio-economists. It requires a permanent and intensive dialogue between the

various specialists, with combined field visits when important disagreements occur (which is not rare).

AGRICULTURAL DEVELOPMENT PLANNING

This final phase of the study is normally carried out by socio-economists and agro-economists on the basis of the possible alternative (or multiple-use as defined by the above mentioned specialists for each area delineated on the map.

Planning specialists, however, do not take only into consideration ecological or other technical criteria; they also use many other criteria of micro and macroeconomics such as the foreseeable evolution of offer and demand for each commodity whose production is envisaged, evolution of costs of production, etc. They also use sociological criteria such as the technical level of farmers or ranchers and the foreseeable evolution of this level in the coming say 20 years; legal criteria such as structure of land tenure and ownership and its evolution, land reform, etc,; financial criteria such as credit facilities, opportunity cost investment possibilities and rate of return versus other types of investments; administrative and political criteria such as government's policy for socio-economic development and national self food reliance.

There is no doubt, however, that the basis remains the evaluation of environmental conditions and potential through phytoecological surveys. One could therefore say that such phytoecological studies are necessary but insufficient for a sound and rational planning of land use and agricultural development.

COST OF SURVEY

I. Inventory. 0.20 to 0.40 U.S. dollars per hectare for a minimum inventory unit area of 1 million hectares.

II. Mapping. 0.20 to 0.40 U.S. dollars per hectare, over a minimum area of 1 million hectares.

III. Publication of maps (colour) and reports. 0.10 to 0.20 U.S. dollars per hectare.

IV. Land use planning. 0.20 to 0.40 U.S. dollars per hectare.

Total Cost = 0.50 to 1.00 U.S. dollars per hectare.

Approximately 50% of the expenditure is personnel salaries and other benefits, based on the following budgetary costs as used in 1980 in the U.N. system:

--Professionals $70,000 U.S.$/yr
--Technicians $35,000 U.S.$/yr
--Secretaries $20,000 U.S. $/yr
--Unskilled labor $5,000 U.S. $/yr

Some Practical Data

Composition of an inventory team

1 ecologist/yr	
1/2 soil scientist/yr	for each million
1 technician/yr	hectares inven-
1 secretary/yr	toried
2 unskilled laborers/yr	
1/2 driver/yr	

Composition of a mapping team

1 ecologist/yr	for each million
1/2 photointerpreter/yr	hectares mapped
1/2 draftsman-carto-grapher/yr	at 1/50,000 to 1/200,000 scale
1 driver/yr	

Composition of a land use capability team *

6 man month ecologist
3 man month agro-economist
1 man month forest engineer
1 man month animal production specialist
1 man month sociologist
6 man month technical assistance
6 man month draftsmen
12 man month secretaries

*for each million hectares at the scales of 1/50,000 to 1/200,000.

--Number of exhaustive releve's that a full time ecologist can do 4-8 per day of field work (during the growing season), i.e., 250 to 500 per year.

--Minimal number of releve's for each plant community inventoried, for a valid statistical analysis: 10.

--Composition of an inventory term for each million hectares:
1 ecologist
1/2 soil scientist
1 technical assistant
2 unskilled laborers
1 driver

--Proportion of time spent in the field, 30-33%.

--Proportion of time spent in office and laboratory, 66-70%.

--Time necessary for mapping one million hectares: 6-12 months for a team composed of:
1 ecologist
1/2 photointerpreter
1/2 draftsman
1 driver

A FEW APPLICATIONS OF PHYTOECOLOGICAL STUDIES

1. Prospecting for genetic plant material

Inventory makes it possible to discover individuals or populations in various species having abnormal ecological behaviour. Those are usually ecotypes or races with particular genetic attributes that may be useful in breeding programs. Inventory and mapping make it possible to localize such plants or populations (and, if need be, to take preservation measures).

2. Extrapolation of experimental data

In principle, all experimental data obtained in a given site of a given plant community is extrapolable with a high confidence level to all sites occupied by this community, using some minor adjustments on density, plant cover, etc. Generalization of experimental data thus becomes possible with security. This, of course, concerns crops as well as range and forest.

3. Determination of climatic characteristics in watersheds having no, or insufficient, instrumental records

Vegetation being very sensitive to rainfall (amount and distribution) correlations between this variable and ecological groups are particularly easy to show and allow for the safe estimation of rainfall and delineation of isohyets on watersheds, a fact which is, naturally, most useful to hydrologists, foresters, etc. The same applies to winter temperatures to which vegetation is also very responsive. This is extremely useful in selecting cultivars or species of crops or trees to be introduced in a given area having no instrumental records or having records on too short a period to be reliable.

There are many more possible applications that time and space do not allow me to discuss here.

The Mali Land Use Project:

A Multiple Resource Inventory in West Africa[1]

B. Dean Treadwell[2] and John Buursink[3]

Abstract.--The Mali Land Use Project is an inventory of the soil, vegetation and water resources of the Republic of Mali in West Africa. It encompasses 575,600 square kilometers in the southern half of the country and includes Saharan, Sahelian, Soudanian and Guinean Bio-Climatic Regions. Contrast enhanced, false-color composite Landsat imagery is the primary interpretive base. Forty scenes have been digitally mosaicked and reformatted to conform to 65 - 1:200,000 scale topographic maps. A dual 35 mm camera system is used to acquire simultaneous 1:20,000 and 1:2,500 scale color aerial photography to supplement Landsat image interpretation and the substantial ground data collection effort. A dual 70 mm/35 mm camera system is an integral part of a sampling framework designed to provide statistically valid estimates of range productivity, and an independent evaluation of map accuracy. In addition to describing project methodology, this paper discusses costs and suggests ways to improve the application of remote sensing technology for operational, regional resource inventories.

INTRODUCTION

In 1977, the Government of the Republic of Mali (GRM) requested the United States Agency for International Development (USAID) and the Fonds d'Aide et de Cooperation (FAC) of France to assist in making an inventory of the land and water resources of Mali south of the Sahara Desert. The Mali Land Use Project began in late 1979 under the direction of TAMS Engineers and Architects, New York, with its two subcontractors, the Environmental Research Institute of Michigan (ERIM) and American Ag International (AAI) of Tucson, Arizona.

Mali is a landlocked country in West Africa, bordered by Senegal and Mauritania to the west, Algeria to the north, Niger to the east, and Upper Volta, Ivory Coast and Guinea along the south. While the Senegal River drains the western portion of the country, the primary drainageway is the Niger River, which commences in the mountains of Guinea, flows northeast through central Mali to the southern edge of the Sahara near Timbuktu, then loops to the southeast into Niger. During the annual flood a vast inland delta develops and rice production is a major activity. Four bio-climatic regions are represented in Mali. From north to south, these are the Saharan, the Sahelian, the Soudanian and the Guinean. Mean annual rainfall ranges from less then 200 mm in the north to 1300 mm in the south.

This paper summarizes the objectives of the Mali Land Use Project, describes the methodologies adopted, discusses costs, and presents initial recommendations for implementation of other regional, multiple resource inventories in semi-arid environments.

OBJECTIVES, PROJECT AREA, DURATION AND PRODUCTS

The objectives of the Mali Land Use Project are three-fold:

1) to compile complete baseline information

[1] Paper prepared for the international workshop, Arid Land Resource Inventories: Developing Cost-Efficient Methods, November 30 - December 6, 1980, LaPaz, Mexico.

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on the soil, water and vegetation resources of Mali;

2) to evaluate this resource data-base and to provide the GRM with the necessary information to make informed decisions on resource allocation; and

3) to train Malians to continue resource inventory and planning activities.

The project encompasses 575,600 square kilometers, an area approximately equivalent to twice the size of Arizona. The actual boundaries are 17°30' north, 1° east and the southern and western limits correspond to the borders of Mali.

The total period of time allotted for the inventory is two years plus an additional six months for final editing and printing of all maps and the report.

Products include both a written report and a map atlas. The written report will review the documented data collected during the project, provide detailed descriptions of soil and vegetation resource components, indicate productivity data for agricultural and rangeland resources, and address potential yields under differing levels of technological input. The 1:500,000 scale map atlas will include the following thematic maps:

1) Soil/Vegetation Units
2) Water Resources
3) Current Land Use
4) Land Capability
5) Water Resource Potential

METHODOLOGY

The methods adopted to complete the data acquisition and evaluation objectives of the project are time-intensive, i.e., they are intended to provide the GRM with the maximum resource information within a relatively short period. Project activities can be divided into four phases: 1) Establishing an Information Data Base, 2) Interpreting Remotely Sensed Data and Collecting Ground Truth Information, 3) Analysing and Synthesizing all Data Collected, and 4) Training Malian Counterparts.

Establishing the Information Data Base consists of two major tasks. First, is the systematic collecting and filing of all existing studies and pertinent references. This was accomplished using standard documentation techniques. Second, was the acquisition of Landsat imagery. This is discussed in this paper.

Interpreting Remotely Sensed Data (both Landsat imagery and aerial photography) and Ground Data Collection were essentially concurrent activities. Although there was considerable emphasis on the use of remote sensing techniques, there was also a substantial commitment to on-site data acquisition. Approximately 25-30 percent of the total man-power was allotted to this activity. The majority of this work was accomplished with four-wheel drive vehicles, but a helicopter will be used for access to selected sample sites. Although the published maps will be at the scale of 1:500,000, preliminary interpretations and ground data collection are based on 1:200,000 image quads. The minimum mapping unit defined for particularly significant features is 25 square kilometers. On the final map, most cartographic units will combine several classification categories into mapping complexes. All ground data collection sites are accurately indicated on the base maps. Detailed field forms are completed and ground level stereo photographs are taken at each site.

Analysis and Synthesis is currently being done on the basis of existing data. In the water resources field, for example, most of the data required for the inventory was already in existance, but required systematic analysis. Long-term streamflow data of the Senegal and Niger rivers from Mali and adjacent countries is currently being computer processed to produce tables and frequency diagrams of monthly and annual mean discharges. Groundwater data was available from numerous small scale hydrogeological maps completed for different localities and from several thousand wells and boreholes throughout Mali. Analysis of agricultural and rangeland productivity is scheduled for summer, 1981.

The majority of the Malian counterpart training is accomplished through daily interactions relative to all aspects of the project, including management, equipment acquisition, field logistics, classification development, aerial camera operation and imagery interpretation. In addition, a series of seminars are scheduled and one counterpart from each discipline will be selected for Master's level training in the United States.

There are several aspects of the methodology which have proven to be particularly advantageous during the course of this inventory. In this paper we have chosen to elaborate on the following subjects: 1) Acquisition and Processing of Landsat Imagery, 2) Use of Small Format Cameras to obtain supplemental aerial photography for both mapping and for use in a range productivity sampling design, 3) the Statistical Sampling Design itself, and 4) Development of the Vegetation Classification System.

Acquisition and Processing of Landsat Imagery

Landsat imagery was used both as the geographic information base and as the primary tool for resource delineation. Forty scenes were required to cover the project area. Emphasis

was placed on obtaining state-of-the-art imagery. During an exhaustive search and evaluation of all available imagery, it was discovered that within the limitations imposed by individual spectral band quality, cloud cover and the occasional satellite malfunction, the final list of suitable computor compatible tapes (CCT's) was not extensive. Indeed, for several scenes, our selection was restricted to only one or two choices. Accordingly, the coverage selected necessarily included all seasons of the annual cycle and spanned four years. While this is not an optimal situation, especially in environments where herbaceous vegetation is only present for a limited time, it is, none-the-less, one of the realities of using Landsat imagery. The project plan does allow for a limited number of additional CCT's to be used either for replacement of inferior scenes or for multi-temporal analysis of selected areas.

The Landsat digital data was contrast enhanced and printed as false color composite images. Edge enhancement was performed on one scene for evaluation and was judged to be detrimental to interpretation because it tended to make natural patterns appear too blocky and be confused with a cultural pattern produced by slash and burn agricultural practices. In addition to geometric correction, scene data from adjacent CCT's was digitally mosaicked and reformatted to conform to 1:200,000 topographic maps. This required combining as many as four separate scenes using newly developed computor techniques. The resulting "image-quad" format has proven to be quite useful for both geographic data storage and for accurate location of ground data collection sites. A total of 65 image-quads were produced at three different scales:

1) 1:1,000,000 provided a general overview of the entire project area and for initial stratification of biophysiographic units;
2) 1:200,000 provided the base map for resource interpretation and for field navigation; and
3) 1:500,000 will be the published map scale as well as the geographic reference for surface water and geohydrological, sociological and regional planning themes.

In addition to the color imagery, a single-band black and white image will be used as the base for the published map atlas.

Aerial Photography With Small Format Cameras

Two small format camera configurations for vertical aerial photography were adapted to compliment the Landsat imagery interpretation and ground data collection activities. The first configuration uses dual 35 mm cameras to collect information required for general reconnaissance and mapping. One camera equipped with a 24 mm lens exposes a continuous strip of photography with 60 percent overlap. The other camera uses a 200 mm lens to take very large scale stereo pairs at regular intervals along the continuous strip. At an approximate altitude of 1700 feet above ground level (AGL), the wide angle lens produces a nominal scale of 1:20,000 and the telephoto lens produces 1:2,500 scale photos. The smaller scale continuous strip photography is used for stereo terrain analysis, accurate transect location on the Landsat imagery, image-type correlations, and precise location of the large scale stereo pairs. These latter photos are used to recognize certain diagnostic tree and shrub species, ground surface conditions, and to estimate both woody and herbaceous vegetative cover. Locations of these transects are selected to bissect a variety of image-types and thus facilitate extrapolation from ground truth sites to Landsat image patterns.

The second camera configuration uses both 35 mm and 70 mm formats to acquire aerial photography for quantitative sampling of range productivity. Both cameras will expose continuous strip photography. At an altitude of 3,000 feet AGL, the 35 mm camera with a 24 mm lens will acquire 1:38,000 scale photos while the 70 mm format camera with an 80 mm lens will produce 1:11,500 scale photos. The smaller scale 35 mm photography will again be used to locate sample strips on the Landsat imagery and to navigate to the precise center point of randomly selected 70 mm frames via vehicle or helicopter for ground sampling. The larger scale 70 mm photography will be used primarily to identify vegetation type and to estimate productivity. The 70 mm format was selected because its enlarged areal coverage was more appropriate to the sampling framework, and because of its better resolution capabilities.

Due to refrigeration and processing limitations, all film used was Ektachrome 200. Haze compensating filters were used and the resulting color renditions were quite satisfactory.

Statistical Sampling of Rangeland Productivity

Another major facet of the project is the estimation of agricultural and rangeland productivity. Agricultural production projections can be derived from the maps and available data. Conversely, very little reliable data exists on a country wide basis for rangelands and thus this task is an integral objective of this project. To best achieve this objective, it was decided to develop an operation methodology which would yield statistically valid figures and would be repeatable in future years. This methodology is summarized below.

After the project area has been mapped by a combination of Landsat image interpretation, ground data collection and supplemental reconnaissance aerial photography, the total areas for

each soil-vegetation unit can be determined. Next, based on both on-site and existing corollary data, the importance of each type for range productivity can be qualitatively ascertained. A combined value of the total areal extent and relative importance is then used in a weighted random sample to select sample sites.

Initial sample stratification areas of 9 x 9 kilometers are selected using the weighted random values from a grid superimposed over the entire project area. Within each initial sample area selected, a series of aerial photo transects (.9 x 9 km.) are again randomly selected and flown using the dual 70 mm/35 mm camera configuration. From each transect, 2-3 70 mm photos will be selected and used to interpret biomass. The center of these photos also define ground sample locations. Thus, the final step in the quantitative data collection for range productivity will be on-site verification of the resource type, and clipping and weighing of actual standing biomass. All sampling photography and ground data collection will be accomplished during the fall period immediately after the summer rains because this is the peak productivity period. The primary advantage of the weighted random sample is that emphasis can be given to more important types, while at the same time maintaining statistical validity.

An additional benefit of the randomly selected sampling photography is that each location is an independanct site and can therefore be used to statistically evaluate the accuracy of the map. Subsequently, any of the ground data collection sites or the aerial photography can be used to further refine map delineations and/or resource identifications.

Development of the Resource Classification System

Although the final product will reflect combined soil-vegetation units, it was first necessary to acquire a basic understanding of the individual resources and develop separate classification systems. The soil classification adopted was based on the USDA Soil Taxonomy. With the vegetation classification, however, preliminary field reconnaissance and review of plant community classifications published from more localized investigations provided an early surprise.

It is well known that the vegetation of West Africa has been drastically altered by centennia of subsistence agriculture, burning, selective wood cutting, intense grazing and severe draughts. What perhaps is not so well known is that these alterations have rendered the traditional classification categories of forest, woodland, savanna and grassland to be rather meaningless. Field observations revealed that dryland agricultural parklands with a canopy of economically useful native trees, abandonned agriculture tree or shrub savannas, and "natural" woodland communities were in reality only seral stages of the same vegetation type. The physiognomic differences merely reflecting the selectivity of tree and/or shrub cutting and the length of time since abandonment. Accordingly, it seemed more suitable to approach vegetation classification with an emphasis on species composition, and their ecological relationships to climatic regimes, geographical affinities, and cultural influences. This is being accomplished by analysing our own field data for indicator species groups using species/stand matrices. Relationships and vegetation types derived by this method are then compared to other published vegetation descriptions to complete and refine the classification.

INVENTORY COSTS

The current cost estimate to complete the inventory is about 3.8 million dollars. In terms of dollars per square kilometer the cost is relatively high at $6.60/km^2. However, considering the five different land and water resource map products being produced, the actual cost per theme per square kilometer is only slightly more then $1.30.

The main cost component (nearly 75 percent) is due to the high level expatriate staffing required to implement the Mali Land Use Project at this time. A resident staff of ten scientists are involved full-time in this inventory with the assistance of an equal number of Malian technical personnel. The total project effort requires 274 man-months of expatriate staff at an average cost of 10,000 dollars per man-month. This large staff was required because Mali's current emphasis on rapid agricultural development necessitated the inventory to be implemented at this time, and not at a later date when enough trained Malian scientists would have been available to do this work at considerably less cost. It is expected that the higher cost of the inventory will be offset by the advantage of having the information available years earlier.

The use of state-of-the-art Landsat imagery was a rather minor cost relative to the entire project. The total expense for acquisition and processing of CCT's to contrast enhanced, color composite images corresponding to 1:200,000 topographic maps was less than 150,000 dollars. This includes photographic color matching and reprinting nearly two-thirds of the image quads. The imagery cost per square kilometer is only $0.25 which is further reduced to $0.05 on a per theme basis.

The use of small format cameras for supplementary aerial photography is also a cost-efficient technique. Although we had cameras available for our use, adequate 35 mm camera systems with motor drive units and 250 exposure film backs can be

obtained for less than $2000.00. Our total color film and processing budget did not exceed $10,000 and aircraft rental which included visual reconnaissance and verification overflights was less than 60,000 dollars at $320/hour. A camera mount was fabricated in Mali at a negligable cost. Thus, for less than 90,000 dollars, we obtained large scale aerial photography adequate to statistically represent the entire project area. This allowed us to save considerable time afield by facilitating correlation of image interpretation and ground data collection. In addition, we were able to determine the amount of inclusions and sub-types within our mapping units, independently evaluate the accurace of our maps, and establish a statistically valid sampling framework for determining range productivity for the entire project area.

Based on our experience and the cost of this project, we can recommend the increased use of remote sensing techniques (both enhanced satellite imagery and supplemental aerial photography) as cost-efficient methods for reducing the costs of regional resource inventories.

DISCUSSION AND RECOMMENDATIONS

We feel the success and lessons learned in the Mali Land Use Project can make some important contributions to the effective use of remote sensing technology for regional resource inventories.

Several significant operational constraints on the use of Landsat satellite imagery became very apparent during the progress of this project. We feel that, in general, these are not prohibitive problems that should preclude the use of Landsat. However, they should be carefully considered during project design to mitigate their potentially detrimental effect.

The first of these constraints is the limited choice for selecting optimal dates and image quality for all scenes. This was not an insurmountable problem in this project although several of the scenes were less than desireable. The project plan can mitigate this situation by allowing for additional imagery to be acquired during the course of the project, or by allowing for additional field time in areas where imagery is not adequate.

Another consideration pertinent to regional inventories using numerous Landsat scenes concerns color balance. The variety of seasons and years represented by the imagery makes color balancing a formidable task. If several scenes are to be digitally mosaicked to conform to a topographic map format (as was done in this project) the task is further compounded. Yet, our experience has shown that the capability for image signature extension is very important for cost-efficient surveys. Field work cannot always be planned on a per quadrangle, or even a per scene basis. More typically, travel routes intersect several base maps and/or images and it is not practical to re-train for feature-image correlations at each boundary. We can offer several suggestions relative to this problem. First, the most useful color balance for the particular objectives of the project can only be determined by evaluation of preliminary images in the field and this activity should be incorporated into the project schedule. Second, when color balancing is attempted over numerous scenes (forty in our case) it is necessarily at the expense of within scene contrast. There are limits to the dynamic range of films and when it is stretched to include both dark forest lands as well as highly reflective sand dunes, the more subtle variations within either extreme may be lost. For our project, maximum contrast within scenes was achieved through digital contrast stretching techniques and subsequently, a best-efforts color balance was accomplished through photographic reproduction techniques. With this approach, we maintained excellent color contrast as well as very reasonable color matching between image quads.

The third, and most severe constraint, is the potential for long delays in acquiring CCT's and subsequent image production. In our project, CCT's were ordered within weeks of the contract award, yet the last tape was not received for nearly ten months. This imposed severe problems for a work plan scheduled for a two-year period. Proper implementation of multi-stage analysis was not possible because the 1:1,000,000 mosaic could not be produced. Field work could not be planned in an efficient manner because missing images necessitated numerous return trips to the same regions.

The only sure solution to this constraint is to allow adquate time for CCT delivery. We feel that resource inventories of this magnitude should provide or a one-year "start-up" period. This would provide enough time for CCT acquisition, processing of preliminary images, field evaluation, subsequent color balancing and image production. Benefits of this start-up period also extend beyond timely image availability. During the field evaluation of preliminary images, logistical situations can also be determined to facilitate a more efficient operational phase later. Also during this in-country visit, a realistic evaluation of living conditions can be ascertained so future expatriate staff can be properly prepared. Documentation activities can also be accomplished during this period.

As a concluding statement, we believe that close interaction between the field team and the image processing facility is essential for the successful use of Landsat imagery for regional resource inventories. Each project has its unique aspects, if not in objectives and scope, then certainly in setting. Accordingly, Landsat imagery must address these unique aspects as a custom product.

RESUMEN

El Proyecto Para la Utilización de la Tierra de Mali es un inventario del suelo, la vegetación y los recursos de agua de la República de Mali al Oeste de Africa. Esta cubre 575,600 kilómetros cuadrados al sur del país e incluye las regiones bio-climáticas del Sahara, Sahelian, Soudanian, y Guinea. La imágen compuesta de Landsat de contraste realzado a color es la principal base interpretativa. Se han obtenido cuarenta escenas en mosaicos digitales y se han reconstruído para ajustarse a mapas topográficos de escala 65-1:200,000. Se utiliza un sistema dual de cámara de 35mm para obtener fotografía aérea simultánea de color a escala 1:20,000 y 1:2,500 para suplementar la interpretación de la imágen Landsat y los grandes esfuerzos para la colección de data sobre suelos. Un sistema dual de cámaras de 70mm y 35mm es una parte integral del marco de muestreo diseñado para proveer estimados válidos, estadísticos sobre la productividad del campo y una evaluación independiente de la precisión cartográfica. Además de describir la metología del proyecto, este trabajo discute los costos, y sugiere medidas para mejorar la aplicación de la tecnología de percepción para el inventario operacional y regional de recursos.

Inventory Planning — Moderator's Comments[1]

H. Gyde Lund[2]

Abstract--An overview and highlights of papers presented on the Inventory Planning Panel are given.

Introduction

Inventories fail or appear to fail because they are either poorly planned, executed, or misused. Unskillfully planned inventories usually result from inexperience, ill-defined objectives, or failure to consider likely constraints and problem areas.

Poorly executed inventories result from lack of quality control or interest. Misuse may develop from the failure of the inventory designer and manager to clearly define objectives and goals of the inventory.

All these potential failures may be eliminated by a well-thought-out and executed formal inventory plan. Proper planning, therefore, is the most important phase of an inventory. It is particularly important in the arid regions of the world where the potential costs could exceed the monetary benefits returned from the resources.

The purpose of this panel is to provide the designer of the arid land resource inventory with some useful tools and examples to guide his development of a plan.

The Inventory Plan

Husch (1971) provides an excellent outline of what is an inventory plan. Even though he uses a forest inventory situation, the planning sequence can be used to develop a plan for any resource. In short, the plan should spell out:

1. Purpose of the inventory, issues and problems.
2. Information required, available and to be collected.
3. Description of the area.
4. Manpower, funding, and time frame constraints.
5. Inventory design.
6. Manpower, funding, and time requirements.
7. Measurement procedures.
8. Compilation procedures.
9. Reporting of results.
10. Maintenance of the system and files.

The previous panels in this workshop have discussed the characteristics of the arid lands, the information needs and the inventory challenges or constraints with which we are faced

This panel discusses tools that can be used to properly design the inventory. To add dimension to the topic, the panel deals with examples of planning techniques and on-going inventories covering a diverse range of subjects.

The Panel Planning Tools

Wiant begins the discussion by providing guidance in properly developing the objectives for the inventory. A four "w" (who, what, where, when) procedure is used.

In coping with the constraints problem, Husch identifies factors which influence the cost of an inventory. Assignment of funds based upon benefit-cost analysis and "a priori" are discussed. "A priori" means that the decisions are taken on how much to spend on an inventory before establishing the inventory specifications. Zeide addresses the problem of optimal allocation of time between travel and measurements. Unexpectedly, he arrived at the conclusion that optimal solution is impossible.

Wensel provides an operational survey planning model that can be used to examine alternative multivariate designs. Nichols introduces additional considerations in planning - that of the physical characteristics of the resources to be inventoried. Procedures for auto or intra correlation analysis are given.

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[1]Paper presented at the Arid Land Resource Inventories Workshop (La Paz, Mexico, November 30 - December 6, 1980).

[2]H. Gyde Lund is Project Leader, National Inventory Techniques Research Work Unit, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, USA.

The On-Going Inventories

Several papers on inventory designs are scattered throughout the panel. Felger et al., present a system for identification and sampling of naturally occurring, potential feedstocks in the arid regions.

Medina, Vasquez, and Guiterrez, outline a planning scheme for determining inventory needs applicable for range and livestock management. Recreation opportunity is the thrust of the paper by Brown et al. A planning and inventory process suitable to the arid regions is presented.

Although Canada is not generally regarded as an arid region, it faces many of the same problems that we face here. Welch, Wiken, and Pierce outline some of the inventory techniques Canada is using to cope with remote lands, areas of low economic values, and with public pressures on the limited available resources.

Our panel is completed by a paper by Goebel and Schmude highlighting the planning process the Soil Conservation Service is using to develop a "National Program for Resource Management."

Subsequent panels will discuss in detail other tools - classification systems, remote sensing, sample designs, resource measurement techniques and analytical procedures. Finally, additional research needs will be discussed in the final session of the workshop. The published proceedings will provide the inventory designer with tools to keep his survey on the road to success.

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Clasificación de Tipos de Vegetación de Zonas Aridas y Semi-Aridas de México[1]

Ing. Lorenzo J. Maldonado Aguirre[2]

Resumen.- En el presente trabajo se propone tomar en cuenta para la clasificación de los tipos de vegetación en México las siguientes características de la biomasa: forma de vida, función, tamaño de las formas de vida, forma, tamaño y textura de las hojas y la cobertura de la comunidad vegetal por especie.

Por su situación fitogeográfica, la República Mexicana posee una gran complejidad vegetacional en donde existen grandes variaciones de los cuatro grupos vegetales que se han clasificado en el mundo como lo son: las selvas, los bosques, los matorrales y los pastizales (Cuadro 6).

El estudio detallado de estos grupos, ha permitido identificar diferentes tipos de vegetación en cada una de ellos, los cuales son verdaderos indicadores de las diversas condiciones ambientales, partiendo del hecho de que la vegetación y sus formas de vida son el efecto del clima y del suelo emanado de un modelo impuesto por los procesos genéticos a través del período geológico, siendo la fisonomía una expresión de la forma de vida de los vegetales, es de ir, la fisonomía es el efecto causado por una serie de factores ambientales que actuan interrelacionados y en donde dependiendo de la capacidad para aprovechar estos factores, dependera el éxito ecológico de la vegetación; con esta capacidad se puede evaluar la eficiencia ecológica y la eficiencia productiva de una región.

Para ubicar la fisonomía de los vegetales en unidades q e manifiesten diferencias en la interrelación de los factores ecológicos, se hace necesario utilizar una clasificación que se base en un sistema descriptivo y permita reflejar la estructura de la vegetación tomando en cuenta las características cualitativas y cuantitativas de una comunidad vegetal.

Aunque cada una de las características de la estructura vegetacional puede ser finalmente subdividida, para efectos de la clasificación de los tipos de vegetación solamente se tomará en cuenta las siguientes peculiaridades de la biomasa: forma de vida, función, tamaño de las formas de vida, forma, tamaño y textura de las hojas y la cobertura.

Para poder analizar la estructura vegetacional es necesario determinar las formas de vida de los componentes de la comunidad, lo que permitirá analizar la complejidad de los sistemas naturales ya que cada forma de vida corresponden una serie de organismos que van a interactuar en conjunto con el medio ambiente (Cuadro 1).

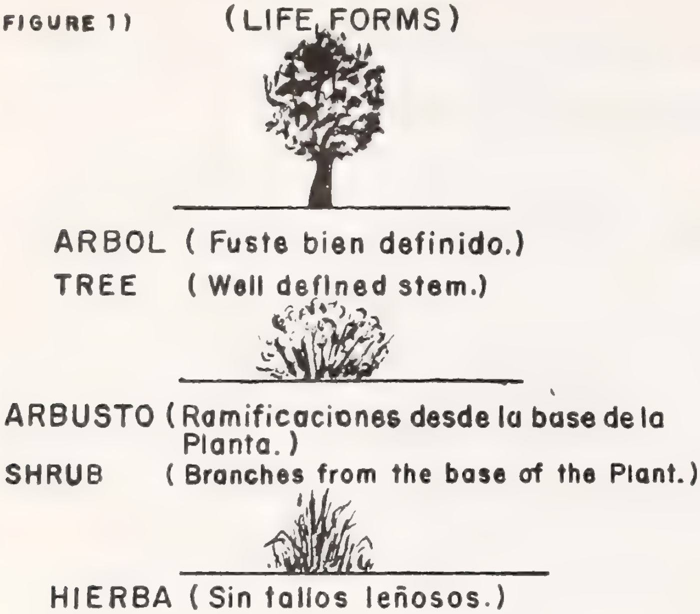
Aunque un tipo de vegetación puede determinarse en base a la forma de vida dominante es necesario determinar otras características del estrato de acuerdo a los niveles altitudinales de los individuos, es decir, el tamaño de las formas de vida, esto proporcionará desde luego una información más precisa de la estructura de la comunidad vegetal (Cuadro 2).

[1] Trabajo presentado en el Evento Internacional "Inventarios de Recursos de Zonas Aridas", La Paz, B.C.S., Mexico, Nov. 30-Dic. 6, 1980.

[2] Ingeniero Agronomo, Director del Centro de Investigaciones Forestales del Noreste-INIF-SARH.

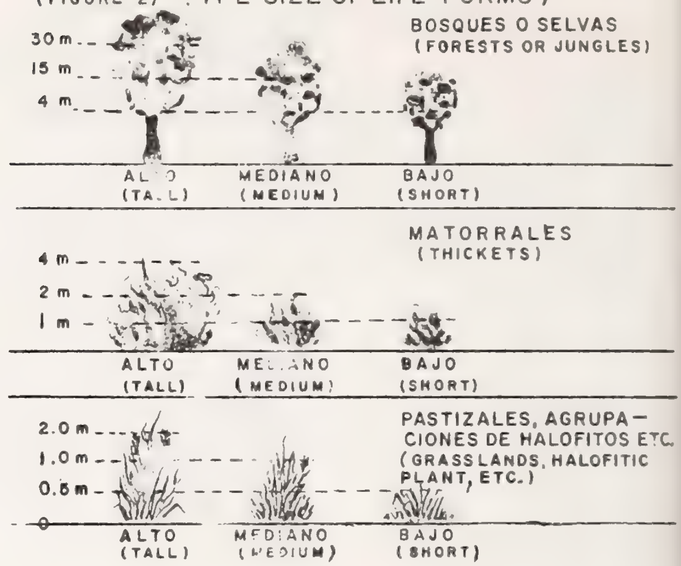
CUADRO 1 FORMAS DE VIDA

(FIGURE 1) (LIFE FORMS)



CUADRO 2 TAMANO de las FORMAS DE VIDA

(FIGURE 2) (THE SIZE OF LIFE FORMS)



CUADRO 3 FUNCION de las FORMAS DE VIDA

(FIGURE 3) (LIFE FORMS FUNCTION)

— PERENNIFOLIA O Siempre Verde	(EVERGREEN) (O PERENNIL)
— SUBPERENNIFOLIA	(SUBPERENNIAL)
— SUBCADUCIFOLIA	(SUBDECIDUOUS)
— CADUCIFOLIA	(DECIDUOUS)
— ESPINOSA	(THORNY)
— INERME	(UNARMED)
— TALLO CARNOSO	(SUCULENT STEM)

CUADRO 4 FORMA, TAMAÑO y TEXTURA DE LA HOJA.

(FIGURE 4) (FORM, SIZE AND TEXTURE OF THE LEAF)

(SUAVES, MEMBRANOSAS, DENTADAS, ETC.)
(SOFTS) (THICK) (DENTADE)

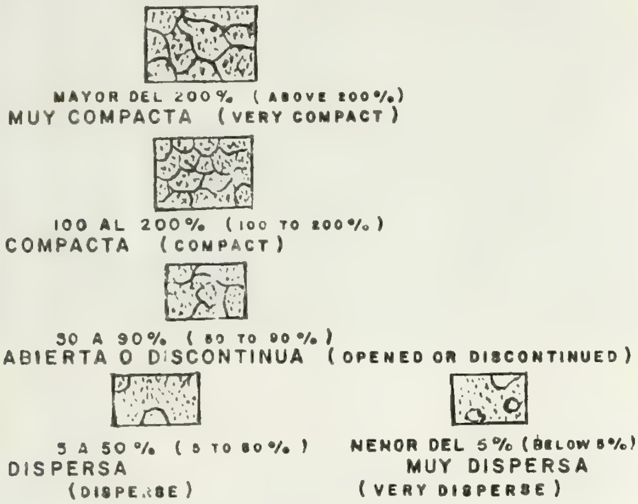
Pensando en terminos de manejo de un ecosistema, es importante determinar las características estructurales de la propia función de las formas de vida ya que esta información indicará épocas y técnicas adecuadas para una explotación dada; además. los datos de la función de las formas de vida detallará con mayor precisión la clasificación de la comunidad vegetal. (Cuadro 3).

Las características estructurales de la forma, tamaño y textura de la hoja son determinantes para poder clasificar un tipo de vegetación y complementa las caracterísiticas anteriormente mencionadas, evitando así cualquier confusión que quedaría resuelta al considerarse la estructura de las hojas. (Cuadro 4).

Ypor último, es importante determinar la cobertura de las formas de vida y así definir la estructura vertical y el patrón horizontal correspondiente para poder relacionar la cobertura con la clasificación de la comunidad vegetal. (Cuadro 5).

CUADRO 5 COBERTURA DE LAS FORMAS DE VIDA.

(FIGURE 5) (LIFE FORMS COVER)



Estos esquemas de clasificación de los tipos de vegetación, facilita el estudio de los diversos fenómenos que rigen el comportamiento de las comunidades en los ecosistemas, ayudando a descifrar la intrincada red ecológica que es la biosfera.

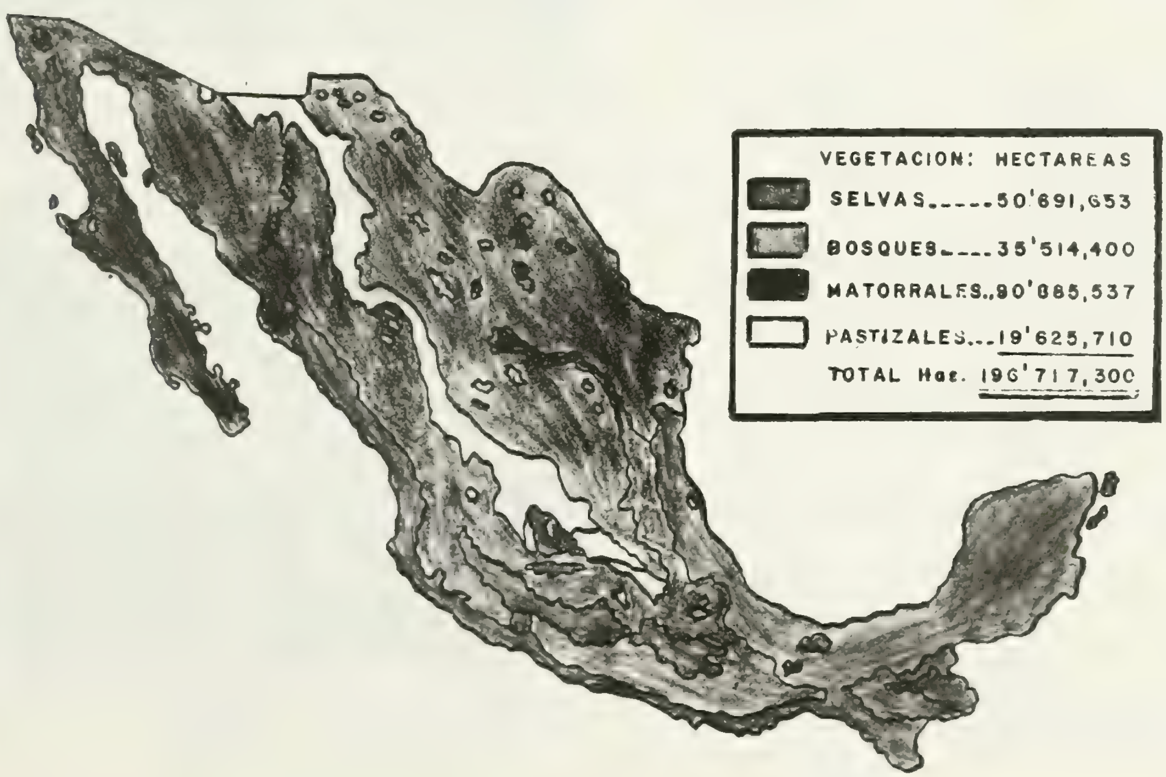
Con el reflejo de la estructura de la vegetación determinada por los conceptos anteriores, se han delimitado 27 tipos de vegetación en las zonas tropicales y subtropicales de México las cuales cubren un 24% de la superficie total del país; se han identificado 18 tipos de bosques que se localizan en las zonas templadas y frías que cubren el 21% de la superficie total del territorio mexicano.

El 55% restante esta cubierto por los grupos de los matorrales y de los pastizales, grupos que se distribuyen principalmente en las zonas áridas y semiáridas de México.

Aunque las estimaciones exactas con respecto a la extensión, delimitación y la definición precisa de las zonas áridas y semiáridas en México, sean aun motivo de discusión, se puede definir como zonas áridas aquellas regiones cuya precipitación pluvial es menor de 325 mm. al año, con una distribución irregular durante el ciclo vegetativo, con una temperatura media anual que oscila entre los 15 y 25° C, con la presencia de no menos 7 meses de sequía, con una cubierta vegetal menor del 70% dominando principalmente especies del tipo xerofítico.

CUADRO 6 GRUPOS DE VEGETACION EN MEXICO

(FIGURE 6) (VEGETATION GROUP'S IN MEXICO)



Las zonas semiáridas, se definen como aquellas regiones cuya precipitación pluvial varía de 325 a 600 mm. al año, con una temperatura media anual de 18 a 22° C, con 6 a 3 meses de sequía: su cubierta vegetal es superior al 70% y la vegetación dominante esta formada principalmente por diferentes tipos de matorrales y pastizales naturales.

En las superficies anteriormente mencionadas, se localiza parte del gran desierto de Norteamérica incidiendo los desiertos Sonorense, el Chihuahuense y el desierto de la Baja California.

Los desiertos Sonorense y Chihuahuense, se han originado principalmente por la ubicación de macizos montañosos, los cuales forman una barrera cerrando el paso a los vientos humedos, provocando así la ausencia de lluvia a las tierras del interior; este fenómeno se produce cuando los vientos humedos chocan con el macizo montañoso, enfriándose a medida que se elevan y descargan toda su humedad en las vertientes del barlovento, cuando estas masas de aire descienden sobre las vertientes del sotavento se han transformado ya en vientos secos que absorben rápidamente la poca humedad del suelo y de las especies vegetales que habitan en esas áreas, formando evidentes condiciones de aridez.

El desierto de Baja California es un desierto costero denominado desierto de nieblas, y se forma por la circulación de los vientos provenientes del poniente, los cuales son enfriados por las corrientes oceánicas que bañan sus litorales.

El 45% de las zonas áridas están cubiertas por matorrales en donde se han clasificado de acuerdo a su fisonomía en 22 tipos de vegetación diferentes:

Matorral sarcocaulescente
Matorral sarcocaulescente subinerme
Matorral sarcófilo
Matorral mediano subinerme
Matorral crasirosulifolio espinoso
Matorral alto subinerme
Matorral arbosufrutescente
Matorral mediano subespinoso
Matorral mediano esclerófilo
Matorral de medanos
Matorral alto espinoso con espinas laterales.
Matorral mediano espinoso con espinas laterales
Matorral bajo espinoso con espinas laterales
Matorral bajo esclerófilo caducifolio
Matorral crasicaule
Matorral alto espinoso crasicaulescente
Matorral arborescente
Matorral arbocrasicaulescente
Matorral inerme parvifolio
Matorral xerofítico tropical
Matorral oligocilindrocaule afilo
Matorral oligoplaticaule afilo

Como se puede observar todos estos tipos de vegetación poseen características fisonómicas diferentes pero que para efectos descriptivos se reagrupan en matorrales inermes, espinosos y subinermes, mencionando únicamente las principales característcas fisionómicas y las especies más importantes desde el punto de vista utilitario contribuyen en cada uno de los grupos vegetacionales.

Matorrales inermes.- Este tipo de matorral ocupa una superficie de 48 millones de hectáreas y se caracteriza por la dominancia de especies arbustivas carentes de espinas, de 1 a 4 m. de altura; entre sus principales componentes desde el punto de vista económico destacan las siguientes: *Larrea tridentata*, que es utilizada para la estracción de antioxidantes, bases para pinturas y barnices para la preparación de fungicidas, ceras abrillantadoras, etc., participan también una serie de arbustos forrajeros como *Atriplex canescens* *Atriplex acanthocarpa*, *Porlieria angustifolia* y otros. (Foto 1 y 2)

Matorral espinosos.- Comprende una superficie mayor de 29 millones de hectáreas localizadas preferentemente en las entidades del norte del país; están formadas por arbustos de 50 cm. a 4 m. de alto, espinosos y de hojas o foliolos pequeños; las especies más conspicuas que se encuentran en esta comunidad vegetal son: *Prosopis spp.*, *Agave lecheguilla*, *Acacia regidula*, *Celtis pallida*, *Parthenium argentatum*, *Euphorbia antisyphillitica* entre otros. (Fotos 3, 4 y 5)

Foto 1.- Matorral inerme parvifolio, con dominancia de *Larrea tridentata*.

Foto 2.- Atriplex canescens, utilizada como forra je.

Foto 3.- Matorral crasirosulifolio espinoso, con Agave lecheguilla.

Foto 4.- Parthenium argentatum, utiliza do en la industria para la extraccion de hule.

Foto 5.- Euphorbia antisyphillitica, fuente natu ral de cera.

Matorral subinerme.- Este tipo de vegetación cubre una superficie mayor de 9 millones de hectáreas y lo forman arbustos de 1 a 4 m. de altura, inermes, pero con la participación de algunos elementos espinosos. Los principales componentes son: Helietta parvifolia, Cordia boissieri, Zanthoxyllum fagara, Pithecellobium bervifolium, etc.

El grupo de vegetacion que junto con los matorrales se distribuyen en las zonas áridas, son los pastizales de donde se han calsificado diez tipos.

Pastizal mediano abierto
Pastizal amacollado abierto
Pastizal mediano arbosufrutesente
Pastizal amacollado arborescente
Pastizal amacollado arbosufrutescente
Pastizal halófito abierto
Pastizal halófito arbosufrutescente
Pastizal inducido
Pastizal amacollado crasicaulescente
Pastizal amacollado arborescente

Los pastizales medianos.- Cubren una superficie aproximada de 16 millones de hectáreas, formado por una cubierta de gramineas de porte bajo, dominando especies como: Bouteloua gracilis, Bouteloua filiformis, etc.

Pastizales amacollados.- Comprenden una superficie de 2.5 millones de hectáreas, formado por gramíneas de porte medio fasciculadas lasespecies más caracterísiticas en esta comunidad vegetal son: Bouteloua curtipendula, Bouteloua uniflora, así como diferentes especies de los géneros Stipa, Muhlenbergia, Aristida y otros

Foto 6.- Yucca filifera, utilizada para la extracción de sarsasapogenina.

Pastizales halófilos.- Este tipo de pastizal esta formado por gramíneas de porte bajo, de 30 a 40 cm. de altura y resistentes a concentraciones de sales en el suelo. Se le localiza en una superficie superior a un millón de hectáreas, principalmente en cuencas cerradas.

Las especies más comunes son: Sporobolus airoides, Hilaria mutica, Hilaria jamessii, Sporobolus pyramidatus, Sporobolus cryptandrus, etc.

Actualmente el uso más generalizado de estas comunidades vegetales es la ganadería extensiva de bovinos y caprinos además, tanto en estos pastizales como en los matorrales se están explotando recursos tales como: Yucca filifera, Yucca carnerosana, la primera para la extracción de hormonas y esta última utilizada en cordelería, Euphorbia antisyphillitica, que posee grandes contenidos de cera, Agave lecheguilla, cuya fibra es utilizada para la fabricación de sacos y cordelería y Opuntia spp., para la producción de fruto y cladodios utilizados como verdura; Parthenium argentatum, para la extracción de hule y Larrea tridentata, para antioxidantes principalmente; sin embargo, en estas áreas existe una gran cantidad de especies que actualmente no son usadas de manera alguna, pero que tienen un gran potencial para ser utilizadas como especies industriales, como ornamentales donde destacan las cactáceas; como alimenticias, medicionales, forrajeras tanto arbustivas como herbaceas; o bien arboles nativos para realizar forestaciones y manejo de cuencas.

Con todo lo anterior, se recalca la importancia de clasificar y delimitar los tipos de vegetación ya que de esta manera se determina la capacidad de las plantas para aprovechar los factores ambientales y con esta eficiencia ecológica determinar la eficiencia productiva de las zonas áridas. (Fotos 6, 7, 8 y 9)

Foto 7.-Opuntia rastrera, especie de gran distribución en las zonas áridas de México.

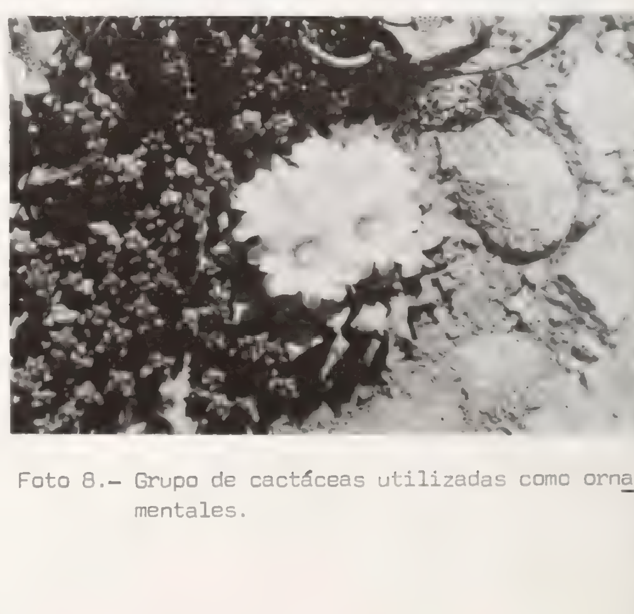


Foto 8.- Grupo de cactáceas utilizadas como ornamentales.

Foto 9.- Investigaciones en zonas áridas para ma_nejo de cuencas.

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ABSTRACT

In order to classify the various types of Mexican vegetation, this paper takes into consideration the following characteristics of the biomass: life form, function, size of life form, shape, size and texture of the leaves, and the composition of the plant community by species.

The USA National Site (Land) Classification System[1]

Daniel L. Merkel[2]

Abstract.--Despite the visibility that "associated ranglands" have received in recent Acts of Congress, statements of research needs, and other public documents, there is an obvious gap between these statements of federal policy and reality. Methods to increase support for management and research on rangelands are discussed.

Your attendance at this conference indicates an interest and perhaps a role in the evaluation and management of natural resources. Therefore, I can assume you are aware of the need for inventory data on one or more resources, as well as analyses of data that will allow you to make meaningful, accurate land management plans and decisions.

Within the United States, many state and federal agencies and private owners manage lands and resources for a variety of uses. As a result, these agencies gather needed resource data individually, then turn to others for additional facts and figures. This is where our problems begin. One finds that others do not collect the same kinds of data on similar resources. Data bases and computer technology for analysis are also often quite different.

It is apparent that a common problem underlies the complex task of resource classification, inventory, and evaluation because there are so many ways to classify land and methods to collect resource information. Therefore, it becomes difficult to combine data from a number of sources.

Everyone looks at the same piece of land differently. Presently, several schemes are used to classify the same piece of landscape and its related soil, vegetation, water, and topography. Classification, then, becomes the foundation for constructing meaningful resource inventories and providing uniform information for assessments, plans, and management programs. Classification is not an inventory in itself. Rather, it serves as the organizational framework for collecting and grouping resource data.

The objective here is to discuss how various organizations and resource disciplines within the United States are developing a classification scheme useful to everyone.

[1] Paper presented at the Workshop, Arid Land Resource Inventories: Developing Cost-Efficient Methods, Nov. 30-Dec. 6, 1980, LaPaz, Mexico.

[2] Daniel L. Merkel is the Project Leader for the National Classification Project, Resources Evaluation Techniques Program, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colo.

The classification system the five cooperating agencies agreed to develop addresses four components of the environment: soil, vegetation, water, and landform. Climatic influences are reflected in the soil and vegetation components. Each component is made up of classes that range from very broad to site specific. The system is taxonomic and hierarchical. Each class within each component is an integral part of the next higher class, similar to the taxonomic classification for plants and animals.

The system permits data to be combined horizontally across classes to develop interrelationships at local or regional levels. This also facilitates data aggregation or disaggregation vertically within components.

System components may be used individually or in combination with others, depending on the need. For example, independent assessments may be combined to assess such values as wildlife habitat or recreation opportunities.

Based on an interagency evaluation in 1979, the following recommendation were endorsed by the Directors of the Fish and Wildlife Service, Geological Survey, and Bureau of Land Management; the Chief of the Forest Service and the Administrator of the Soil Conservation Service:

1. All agencies accepted the component approach as the most useful for their purposes.

2. The soil component was fully accepted.

3. The vegetation component was accepted subject to the following refinements:

    a. The system needs to accommodate existing vegetation.

    b. Terminology describing vegetation classes must be defined and simplified.

c. Methods must be developed to correlate vegetation descriptions, using the system, with those of other systems currently in use by the various agencies.

4. A new water component must be developed. All five agencies have helped complete the first draft of a water classification which will be refined and tested.

5. A new landform component must be developed. Again, the agencies are working together to complete this job. Their first report draft is due in April, 1981.

6. Further evaluation must be made of the relationship between this classification system and mapping procedures.

7. Last, and very important, data gathered through the inventory and analysis processes of these agencies shall be translated into the soil and vegetation components of this classification system.

In addition to these recommendations, the system requires the following refinements. First, further develop the integration of components into ecological response units defined as follows:

"An ecological response unit is a distinct unit of land that (1) includes at least one taxonomic class from each of the components of nearly the same hierarchical level, and (2) responds in a predictable manner to land management or treatment practices."

The second identified refinement was to establish basic relationships between vegetation existing on any given site and climax for that site.

The third item was to develop an understanding of the differences between ecological response units and mapping units.

The following is a brief review of the soils and vegetation components of the system. The soil component utilizes the soil taxonomy approach to classification. It is the procedure used by the National Cooperative Soil Survey of which the Department of Agriculture, Bureau of Land Management, and other national, state, and local agencies are participants.

The vegetation component is made up of several classification schemes. The United Nations System for International Classification and Mapping of Vegetation uses canopy cover and plant structure variables for defining the higher level classes. Mid levels use plant genus with potential for ecological modifiers. Some units may be similar to Küchler's descriptions of potential natural vegetation in the United States. Lower level classes are determined by the species and floristic characteristics of plant communities.

The vegetation component is based on climax vegetation. However, the need to deal with existing vegetation in inventories and evaluations is recognized. In this context, the component relates existing plant communities to climax vegetation. This provides a baseline for planning and evaluating vegetation management programs. The vegetation component consists of the following classes:

- Formation classes are identified by general descriptions of the form and stature of plant communities occupying the land. The five classes are closed forest, open woodland, shrub, dwarf shrub, and herbaceous vegetation.

- Formation subclasses call for more precise foliage descriptions such as evergreen closed forest, deciduous woodland, tall grass, forbs, and so forth.

- Formation groups are separated by generalized climatic modifiers such as temperate evergreen forests, tropical deciduous forests, or evergreen subdesert shrublands.

- Formations require more precise descriptions of vegetation form. Examples are evergreen forest with rounded crowns, temperate deciduous thickets, or sodgrass communities.

- Subformations are recognized by major genera of the plant community such as redwood forest or sagebrush.

- Series are usually characterized by an individual climax specie that dominates the plant community. Examples are ponderosa pine or bluebunch wheatgrass.

- Associations are plant communities of definite composition, presenting a uniform appearance and growing in uniform habitat conditions. Examples are Engleman spruce/subalpine fir/vaccinium, or Idaho fescue/bluebunch wheatgrass/big sagebrush.

The five cooperating agencies are supporting development of the system, and required the classification system in its present form be published as a status report in 1981.

The Resources Evaluation Techniques Research and Development Program is responsible for making the system operational. In turn, each agency will apply it to their own resource inventories and assessments. The Fort Collins, Colorado group will not be doing the actual classification for the various agencies.

Summary

To summarize, the classification system provides for classification of land on an ecological basis according to four components: soil, vegetation, water, and landform.

The agencies working on the system (Bureau of Land Management, Fish and Wildlife Service, Forest Service, Geological Survey, and Soil Conservation Service) have endorsed the component concept. They have agreed to make application of the soil and the completed part of the vegetation components in their respective resource inventories and assessments. Development of needed water and landform components is provided by the efforts of two interagency teams. With interagency guidance, the classification system is being refined so data already collected through other approaches can be incorporated into the system.

The classification is also being strengthened to facilitate data sharing and integration among agencies to improve regional analysis and national assessments, and to enhance local land use planning and on-the-ground resource management. And finally, the intent of the classification system is to provide all interested agencies - national, state, and local - with a tool to:

1. Encourage compatible resource classification and inventory within and among federal and state agencies.

2. Develop resource assessments and appraisals using compatible data.

3. Transfer inventory data and information between compatible data bases.

All three are vital steps for managing the natural renewable resources of the United States in the best interest of its citizens and the environment.

Resúmen

Para resumir, el sistema de clasificación de tierras sobre una base ecológica de acuerdo con cuatro componentes principales: el suelo, la vegetación, el agua y la fisiografía.

Las agencias que trabajan con el sistema (Agencia para el Manejo de Suelos, Servicio de Pesca y Fauna, Servicio Forestal, Inventario Geológico y Servicio de Conservación de Suelos) han endosado el concepto del componente. Aquellas han acordado aplicar los componentes del suelo y de la vegetación en sus inventarios y evaluaciones respectivas del recurso. El desarrolo de los componentes requeridos del agua y de la fisiografía ha sido proporcionado por medio de los esfuerzos de dos grupos de trabajo de agencias diferentes. Con la guía inter-agencia, el sistema de clasificación se encuentra en proceso de refinación, en tal forma que los datos que ya han sido recolectados a través de otros procedimientos se puedan incorporar al sistema.

Se está reforzando la clasificación para facilitar el que los datos sean compartidos e integrados entre diversas agencias para mejorar el análisis regional y las evaluaciones nacionales, así como para aumentar la planeación del uso de las tierras locales y el manejo del recurso. Finalmenta, el propósito del sistema de clasificación es el proporcionar, a todas las agencias interesadas, - nacional, estatal, y local - una herramienta para:

1. Estimular una clasificación y un inventario del recurso que sean compatibles dentro y entre agencias federales y estatales.

2. Desarrollar evaluaciones y valoraciones del recurso que empleen datos compatibles.

3. Transferir datos e información de inventario entre bases de datos compatibles.

Los tres anteriores constituyen pasos vitales para el manejo de los recursos naturales renovables de los Estados Unido en el mejor interés de sus ciudadanos y del medio ambiental.

Arid Land Resource Inventory Based on the Biohydrologic Condition of the Soil Surface[1]

Robert M. Dixon[2]

Abstract.--Economic methods are needed to halt the widespread desertification and irreversible loss of arid land resources. Newly developed science and technology for controlling rainwater infiltration provide a means for arresting desertification and improving these lands for different uses. The first step is to inventory the prevailing biohydrologic state of the soil surface.

INTRODUCTION

Arid land regions occupy a third of the earth's land surface. Soil and water resources in these regions represent two of the greatest unused and underdeveloped land resources in the world today. Because of past improper and short-sighted development, much of this land has been all but abandoned and is presently deteriorating rapidly through the insidious forces of desertification (Biswas 1978, Dregne 1978). Much of the land has been overgrazed and is now capable of supporting only a small fraction of the livestock and wildlife that it could carry if revegetated and properly managed. Overgrazing has denuded some land areas and in others has allowed palatable grasses to be replaced by unpalatable shrubs that provide very little protective groundcover. Some land areas have been farmed either with or without irrigation, and then abandoned in a near barren state.

This land mismanagement and the resulting marked reduction in low-growing vegetation has accelerated losses of the vital and limited soil and water resources through the desertification processes -- runoff and erosion. Once denuded, the soil surface is smoothed and sealed rapidly under the forces of impacting raindrops, thereby reducing infiltration to a small fraction of that for a comparable grass-covered surface (Dixon et al. 1978, Wadleigh et al. 1974). Since rainwater penetrates the smooth sealed surface only superficially, much of it is lost by surface evaporation soon after the rainfall ceases.

New infiltration control science and technology developed during the past 20 years provide a sound basis for redeveloping and improving these lands for a variety of appropriate uses. (Dixon 1978, 1980). The first step in applying this new technology to arid land development is to conduct a resource inventory of the biohydrologic condition of the soil surface. A simple scheme for classifying soil surface properties which exert a controlling influence over infiltration would provide a cost efficient and meaningful basis for this inventory. The principal parameters in the scheme should include (1) soil surface microroughness and macroporosity and (2) kind, quantity and spatiotemporal distribution of vegetation. Such an inventory would not only provide useful information on the stage and rate of desertification, but also would help to identify those land areas having the greatest potential for economic development.

It is the purpose of this paper to outline the conceptual basis for surveying the biohydrologic condition of the soil surface and to briefly discuss important infiltration parameters that need to be evaluated.

SOIL SURFACE CONDITIONS

Infiltration Control

Research, directed to developing new principles and practices for controlling rainwater infiltration, has been conducted in Wisconsin, Montana, Nevada and Arizona during the past 20 years (Dixon 1979). One of the principles evolving from this work is the air-earth interface concept which states that *the*

[1]Paper presented at the Arid Land Resource Inventories Workshop. [La Paz, Mexico, November 30 - December 6, 1980].

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microroughness and macroporosity of the air-earth interface control infiltration by regulating flow of water and displaced soil air in underlying macropore and micropore systems. It was found that this important hydrologic process could be controlled by a factor of 10 or more by hand manipulation of surface microroughness and macroporosity. A microrough, macroporous surface has the capacity to infiltrate high intensity rainfall; whereas a microsmooth, microporous surface will shed most of this rainfall. The microroughness and macroporosity interact to funnel rainwater into the soil and to funnel the displaced soil air out of the soil (fig. 1).

Figure 1A symbolizes the hydrologic condition of the soil surface resulting from overgrazing of rangelands or excessive tillage of croplands, whereas figure 1B represents the condition resulting from perennial grass vegetation in rangelands or mulch cultivation in croplands.

Also evolving from the infiltration control research was a new tillage concept called land imprinting which may be defined as *a land treatment method for mechanically manipulating the microroughness and macroporosity of the soil surface.* (Dixon 1980, Dixon and Simanton 1980). Land imprinting is a primary tillage method performed with machines (imprinters) having raised angular faces which, when forced into the soil, form corresponding patterns of vee furrows. Imprint formation involves soil compressing, shearing and embossing processes occurring in an overlapping and interacting sequence. This sequence is preceded by mulching when aboveground plant materials are present. Imprints are formed without soil surface inversion and without burial of aboveground materials. Land imprinters have the unique ability to transform the microsmooth, microporous surface into a microrough, macroporous surface in a once-over operation to facilitate the revegetation of desertified land (fig. 2).

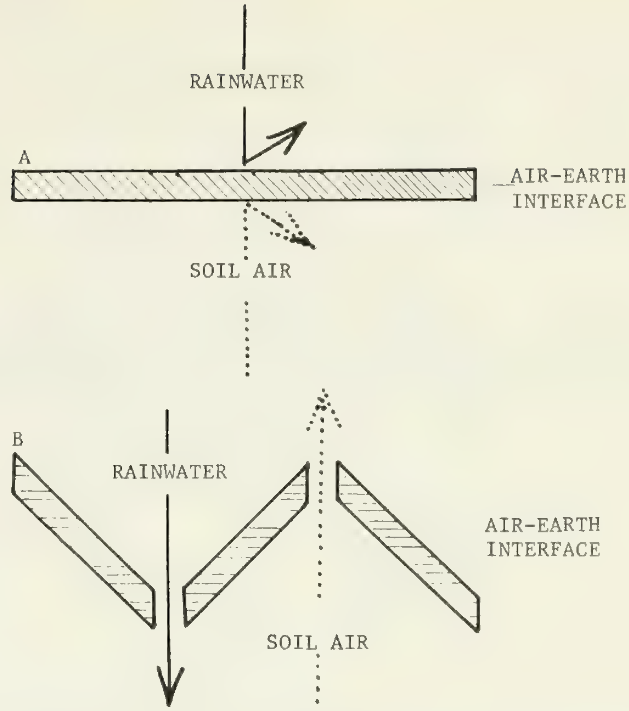

Figure 1.--The microsmooth, microporous air-earth interface (A) severely impedes exchange of rainwater and soil air, whereas the microrough, macroporous interface (B) freely exchanges these fluids.

Figure 2.--A land imprinter operating on desertified rangeland near Tombstone, Arizona to convert the air-earth interface of figure 1A to that of figure 1B.

Desertification

Desertification may be defined as *man-induced land degradation that produces increased aridity of the microclimate experienced by plant communities.* It is initiated by a disturbance of the soil surface that profoundly affects the key hydrologic process -- rainwater infiltration. Infiltration is a primary process that exerts a controlling influence over secondary processes such as runoff, erosion, flooding, evaporation, transpiration, deep percolation, groundwater recharge, and spring and stream flow. Land disturbances that initiate desertification include those produced by tillage and harvesting implements, construction and mining equipment, transportation vehicles, livestock, and man's hand tools and footprints. Such disturbances tend to sequentially (1) decrease vegetal groundcover and increase land barrenness; (2) decrease surface microroughness, surface macroporosity, and rainwater infiltration; (3) increase water runoff and surface evaporation;

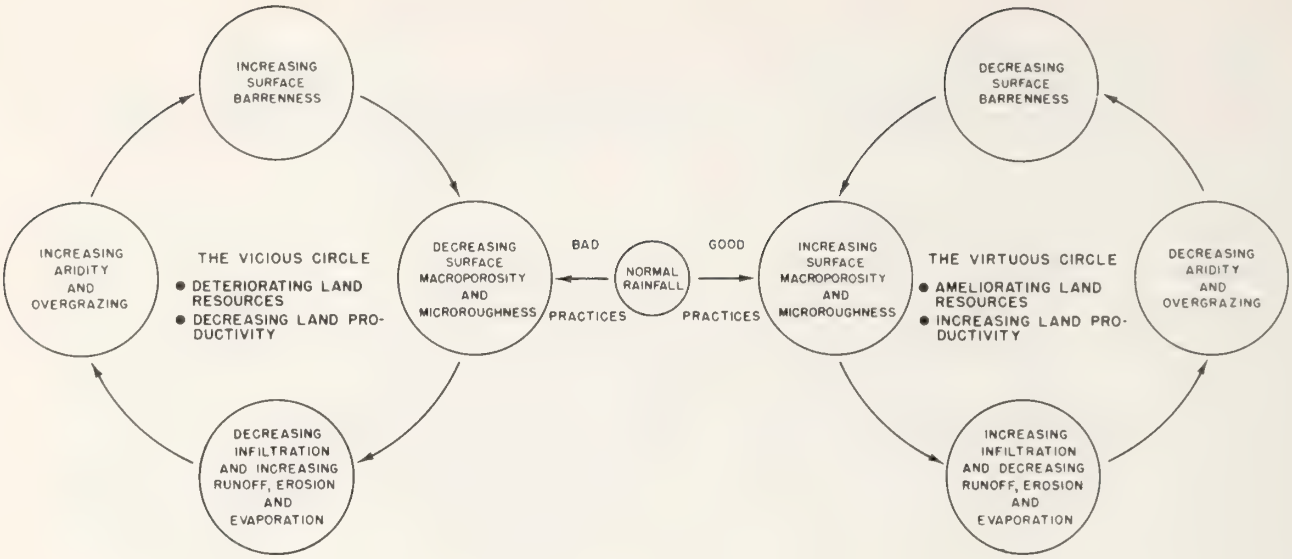

Figure 3.--Bad management practices such as overgrazing of arid rangelands reduce the microroughness and macroporosity of the soil surface, thereby triggering a vicious circle of land deterioration or desertification. Land imprinting is a new tillage method developed specifically to break this circle by increasing surface microroughness and macroporosity, mechanically and biologically (Dixon and Simanton, 1977).

and (4) decrease deep percolation, groundwater recharge, and transpiration. This chain of events which is associated with desertification form a vicious circle as illustrated in figure 3. Repeated disturbances such as moldboard plowing are usually required to perpetuate this cycle of land desertification in humid regions, whereas a single disturbance is often all that is needed in arid regions due to the greater fragility of ecosytems experiencing severe moisture stresses.

In arid zones, desertification often causes an irreversible loss of soil and water resources since accelerated erosion occurs much faster than new soil can be formed (Dregne 1979, Schumm 1979). This net loss in soil usually means that less rainwater and mineral nutrients can be retained for nourishing plants; consequently, desertification decreases the land's capacity to produce vegetation and carry herbivores.

Overgrazing by livestock such as cattle, sheep and goats is the land disturbance primarily responsible for triggering and accelerating desertification of arid lands in virtually every continent. Protective groundcover in the form of low-growing grasses is selectively grazed, thereby severely handicapping this vegetal type in its competition for light and soil moisture with the less palatable shrubs. Consequently, desertification produces a decreasing grass/shrub ratio and declining complexity and stability of plant communities. The soil surface becomes increasingly smooth and microporous and an increasingly greater fraction of the rainwater is dissipated unproductively as runoff and surface evaporation. The simplification of geometry unstabilizes the soil surface with consequent accelerated erosion. This simplification of biohydrological surface condition and the resulting instabilities is consistant with the general complexity-stability concept for natural systems as described by McHarg (1971) and Watt (1968).

Revegetation

Revegetation may be defined as *the reestablishment of plants by man in land areas denuded through land disturbances and the ensueing desertification processes*. It involves stopping and slowly reversing the vicious circle of desertification as illustrated in figure 3. The first step in the revegetation process is to arrest desertification by mechanically converting the microsmooth, microporous land surface to a microrough, macroporous surface to, in turn, infiltrate enough rainwater for germinating seeds and establishing seedlings. The mechanical conversion of the land surface gives only temporary control of infiltration; however, the established vegetation will provide relatively permanent enhancement of rainwater infiltration assuming good grazing management is then practiced.

As a vegetal type, grasses are unexcelled

for enhancing infiltration and reversing desertification. A grass-covered surface infiltrates rainwater up to 10 times faster than a barren desertified surface (Dixon et al. 1978). The grassed surface with litter can infiltrate most of a one-hour maximum intensity rainstorm with a 100-year frequency, whereas a barren surface will shed about nine-tenths of the rainwater from such a storm (figs. 4 and 5).

Grasses, because of their growth form and the leaf litter they produce, are uniquely well-suited to creating and maintaining the microrough, macroporous surface. The multiple vertical stems, with many long narrow leaves extending outward, form a fine-meshed screen capable of intercepting virtually all of the raindrops from intense rainstorms before they reach the soil surface. Those that do slip through, usually strike leaf litter instead of mineral soil. This tight screen of plant material, located near or on the soil surface, absorbs raindrop impact energy and delivers clear rainwater to macropores located in microdepressions. On the other hand, leaf litter thatches the microknolls and ridges, thereby diverting rainwater away from soil air exhaust vents downslope into water intake ports. Grass absorption of impact energy prevents both splash-erosion smoothing of the soil surface and clogging of the macropores with soil sediments. Leaf litter, laced together and anchored by both living and dead grass stems, provides considerable resistance to overland water flow, thereby increasing the effective microroughness of the soil surface. This increased hydraulic resistance is reflected in a greater depth of ponded water which in turn increases not only infiltration rate but also the duration of the infiltration event. Grass litter indirectly enhances infiltration by maintaining large populations of surface burrowing invertabrates and small mammals. These animals, not only increase and maintain surface and subsurface macroporosity, but also increase surface microroughness through their burrowing activities.

By absorbing raindrop impact and by reducing the quantity and velocity of overland flow, a dense stand of grass essentially eliminates splash, sheet, and gully erosion. Grass also stops air movement at the soil surface to prevent wind erosion. Thus, under a grass-covered surface, new soil is formed faster than it is lost and the soil resource improves with time.

Grasses differ in their ability to arrest and reverse desertification through infiltration enhancement and erosion control. Annual grasses provide protective groundcover and feed burrowing soil animals, but for only a short period during and following the rainy season. Fire can quickly destroy a dry grass cover leaving the land barren and in a highly erosive state. In the perennials, bunch grasses provide less effective groundcover than the sod-forming rhizomatous grasses. Additionally, rhizomes

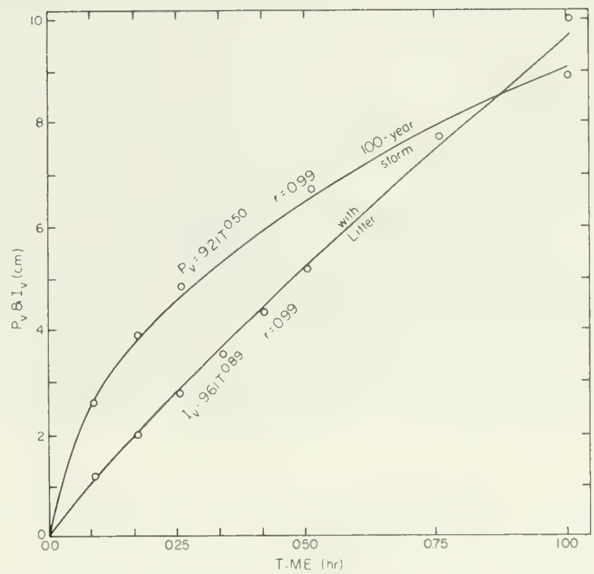

Figure 4.--Precipitation P_V and infiltration volume I_V for grass-litter covered surface with least-square determined Kostiakov equations and correlation coefficients for the linear transforms of these equations (Dixon et al. 1978).

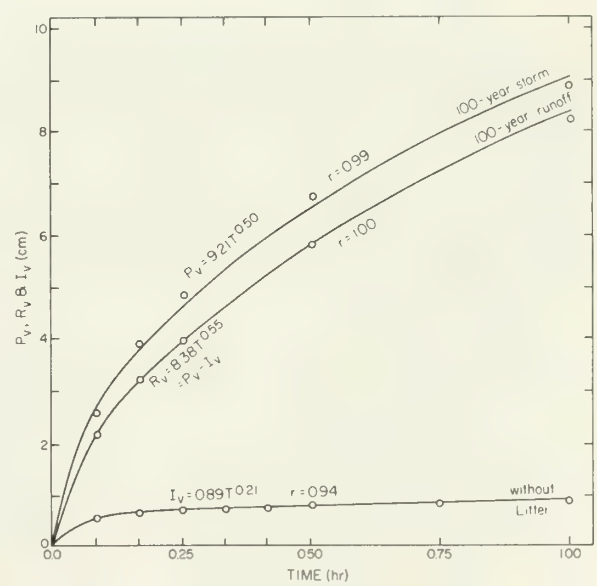

Figure 5.--Precipitation P_V, runoff volume R_V, and infiltration volume I_V for a bare soil surface with least-square determined Kostiakov equations and correlation coefficients for the linear transforms of these equations (Dixon et al. 1978).

are damaged less by overgrazing and fire than the crowns of bunch grasses.

Because of the foregoing important biohydrologic functions of grass, several perennial species should be seeded when the land surface is mechanically manipulated to ensure the biological improvement and maintenance of the microrough, macroporous surface. Once a good stand of grasses becomes well established, redesertification can be avoided by light grazing and browsing of grass and shrubs. Such utilization usually requires stocking rangeland with mixed livestock such as cattle and goats to maintain a high grass/shrub ratio.

CHARACTERIZING INFILTRATION CONTROL PARAMETERS

Biohydrologic Parameters

The biohydrologic condition of the soil surface may be characterized by evaluating a number of biotic and hydrologic parameters. These parameters are interdependant and interact in a complex manner to exert a controlling influence over rainwater infiltration. The magnitude of each of the parameters listed subsequently is relatively large for the ameliorated land condition and relatively small for the deteriorated condition. These parameters affect infiltration through their influence on the key parameters -- soil surface microrughness and macroporosity. Parameters having the most direct influence on the key parameters are listed first.

Biotic Parameters:

(1) Litter surface cover percentage and mass per unit area.
(2) Biomass concentration near the soil surface.
(3) Soil invertabrate populations including ants and termites.
(4) Biomass production per unit time.
(5) Complexity and stability of plant communities.
(6) Stability of vegetal production/consumption ratio.
(7) Uniformity of biomass spatiotemporal distribution.
(8) Grass/shrub and perennial/annual species ratios.
(9) Biomass specific surface (area/mass).

Hydrologic Parameters:

(1) Soil surface microroughness and macroporosity.
(2) Depression storage of rainwater.
(3) Hydraulic resistance of soil surface.
(4) Ponded rainwater depth.
(5) Complexity and stability of soil surface geometry.
(6) Clarity of ponded water.

Soil surface microroughness can be directly measured with a simple mechanical meter that projects surface configurations onto a strip chart via close-spaced, ball-tipped pins (fig.6). Downslope roughness is the most meaningful since these surface irregularities produce depression storage and hydraulic resistance to overland flow.

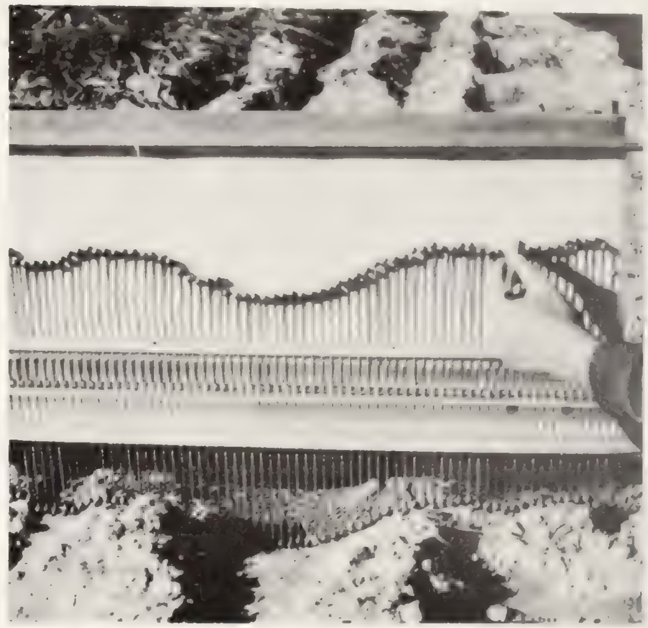

Figure 6.--A microroughness meter sensing the geometry of a splash-eroded imprint (Simanton et al. 1978).

Surface macroporosity can be determined directly by visual and photographic methods after the obscuring litter is removed by a vacumm cleaner or indirectly as a function of the litter itself. Litter, either as mass per unit area or percent groundcover is related to surface macroporosity because it feeds the macropore-forming invertabrates and prevents macropores from becoming plugged by soil sediment during rainfall.

Vegetal Parameters

Since revegetation is often the only economically feasible process for conserving and improving land resources suffering from desertification, the vegetal parameters deserve special emphasis. The spatiotemporal distribution of plants and plant communities greatly affects infiltration, both during the event and seasonally. Infiltration tends to be enhanced by (1) moving aboveground vegetal biomass closer to the soil surface, (2) distributing it more uniformally areally, (3) dividing it into smaller pieces or units to increase specific surface, and (4) distributing it more uniformly, temporally.

Biomass can be moved closer to the soil surface through (1) grazing management that favors low-growing species such as grass, (2) mulching of aboveground plant material, and (3) seeding of adapted low-growing species. Uniformity of horizontal distribution can be improved by increasing the grass/shrub ratio through grazing and revegetation practices. Specific surface of biomass may be increased by mechanical mulching of aboveground plant materials and revegetation directed to increasing biomass of grasses relative to that of shrubs and succulents.

Uniformity of biomass temporal distribution can be improved by increasing the (1) variety of vegetal types (grasses, shrubs, half-shrubs and forbs), (2) number of perennial species relative to the number of annuals, (3) number of species having long growth periods, (4) diversity of plant communities to permit vegetal growth during the four seasonal temperatures and light regimes, and (5) rainwater and soil moisture conservation to moderate the growth-limiting stresses of short-term drought.

Since the objective of infiltration control is to effect revegetation and dedesertification at accelerated rates, vegetal parameters need to be evaluated on an areal or spatial scale roughly approximating the space occupied by individual plants. Thus, a square meter is generally an appropriate sample size for evaluating infiltration and its vegetal parameters.

An example of a vegetal sampling frame, from which both vertical and horizontal distributions of biomass may be obtained, is pictured in figure 7. Cumulative biomass can be graphed as a function of the vertical distance above the soil surface to sharply contrast vertical distributions of biomass for extreme vegetal types such as grasses and shrubs. The cumulative biomass for the first 10 cm above the mineral soil surface is especially important as it profoundly affects both microroughness and macroporosity of the soil surface.

Figure 7.--Cubic-meter frame for sampling spatial distribution of aboveground biomass.

SUMMARY

Generally, arid lands of the world have been mismanged and are currently in various stages of desertification. Overgrazing has stripped the land of its protective cover of grass and has allowed the invasion of shrubby species; however, shrubs provide relatively little protection against accelerated erosion. In advanced stages of desertification, browsing animals eventually kill the shrubs to completely denude the land surface. At this point desertification abatement is exceedingly difficult and costly. Essential parts of biohydrologic mechanisms are either lost or severely damaged causing natural infiltration systems to malfunction. Especially serious are the losses in diversity and stability of complex floral and faunal communities that took millions of years to coevolve from simple unstable ecosystems to complex stable ones. The soil loses its surface microroughness and macroporosity and often much of its surface layer through erosional processes. This soil deterioration reduces infiltration and causes an increasingly greater portion of the rainwater resource to be dissipated as runoff and surface evaporation.

Desertification can be arrested by reversing the downward trend in soil surface microroughness and macroporosity. A land imprinting and seeding machine has been developed for this purpose. It mechanically converts a microsmooth, microporous surface into a microrough, macroporous surface and simultaneously disseminates seeds of adapted plant species. The resulting plant communities will then improve and maintain the microrough, macroporous surface indefinitely if overgrazing does not occur again.

Because of their unique growth form, perennial grasses are unexcelled in desertification abatement. Their heavy concentration of finely divided biomass near the soil surface improves and maintains the microroughness and macroporosity created mechanically with the land imprinter. Consequently seeding mixtures should contain several adapted species of perennial grasses.

The first step in arresting desertification is to inventory the biohydrologic condition of the soil surface to, in turn, determine the stage of desertification and the cultural practices

required for land revegetation. Key characteristics of the prevailing stage of desertification include:

(1) surface microroughness, macroporosity, and infiltration;
(2) grass and litter cover percentages;
(3) soil invertabrate populations;
(4) grass/shrub ratio;
(5) plant community diversity and stability; and
(6) land barrennes, microaridity, surface evaporation, water runoff, water erosion, and wind erosion.

As desertification progresses, characteristics numbered 1 through 5 decrease while those of no. 6 increase. During revegetation or dedesertification, these characteristics change in the opposite direction.

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INVENTARIO DE RECURSO DE TERRENO ÁRIDO BASADO EN LA CONDICIÓN BIOHYDROLÓGICA DEL SUELO SUPERFICIE

Robert M. Dixon

SUMARIO

Generalmente, las terrenos áridas del mundo se han estado manejado mal y estan corrientamente en varios grados de desiertización. El sobre-pastoreo ha arrancado del terreno su cobertura protectiva de zacate y a dejado la invasión de las especie de arbustos sin embargo los arbustos ofrecen relativamente poca protección contra erosión acelerada. En grados advensados de desiertización, el ramoneo de los animales llega eventualmente a matar los arbustos hasta completamente desnudar la superficie de la terreno. A este punto el apaciguarmiento de desiertización es extremamente dificil y costoso. Las partes escenciales del mecanismo biohydrológico se pierden o se dañan severamente causando el sistema natural de infiltración que no funcione bien. Especialmente serio es la perdida de diversidad y establildad de comunidads complejas de floral y faunal que tomaron milliones de años para juntas evolucionar des de simple inestable ecosistemas a unas complejas estables. El suelo pierde su microescabrosidad y su macroporosidad y muchas veces su capa de superficie por procesos de erosión. Esta deterioción del suelo reduce infiltración y causa un incremento en porciones mas grandes del recurso de lluvia que se disipa como escurrimiento y evaporación del superficie.

La desiertización se puede arrestar si se reversa el curso para bajo de la microescabrosidad y macroporosidad en el superficie del suelo. Una máquina para imprimir y siembra se a desarrollado para estó. La máquina mecanicamente convierte una superficie microlisa y microporosidad a una superficie microescabrosidad y macroporosidad y al mismo tiempo disemina semillas de especie de plantas adaptadas. La comunidades de plantas que resultan van a majorar y mantener la microescabrosidad y macroporosidad de la superficie indefinitamente si no ocurre otra vez el sobrepastoreo.

Por causa de la rara forma de crecer, zacates perenes son si compara para el apaciguarmiento de desiertización. Su alta concentración de biomasa dividedad finamente cerca del superficie del suelo ayuda mejorar y mantener la microescabrosidad y macroporosidad que fueron creadas mecanicamente con al impresor de tierra. Por lo tanto mezcladuras de semillas deben de tener varias especies adaptadas de zacates perenes.

El primer paso en arrestando la desiertización es enventariar la condición biohydrológica del superficie del suelo, luego se puede determinar el grado de desiertización y la determinación de practicas de cultivación requeridas para revegetación de la terreno. Las caracteristicas principales de los grados prevalientes de desiertización incluen:

(1) la microescabrosidad, macroporosidad y infiltración;
(2) percentaje de cobertura de zacate y mantillo organico;
(3) población de invertebrados del suelo;
(4) proporción de zacate/arbustos;
(5) la diversidad y estabilidad de la comunidad de plantas y
(6) la infecundidad, microclima árido, la evaporación de la superficie, escurrimiento, erosión de agua y erosión de viento.

Mientras progresa la desiertización las caracterîstics numero 1 hasta 5 decrecen mientras la del numero 6 aumenta. Durante la revegetación estas caracterîsticas cambian para la dirección opuesta.

The Arid Bioclimatic Zone and its Vital Role for Man in Morocco[1]

Mohammed Ellatifi[2]

Abstract.- Covering about 134,000 km^2 (52,300 sq. mi.), the arid bioclimatic zone accounts for about 15% of the total area of Morocco. It is divided as follows:
41,100 km2 (16,100 sq. mi.) in the arid zone with cold winters (m < 0°C [32°F]).
42,400 km2 (16,500 sq. mi.) in the arid zone with cool winters (0°C [32°F] < m < 3°C [37°F]).
47,100 km2 (18,400 sq. mi.) in the arid zone with temperate winters (3°C [37°F] < m < 7°C [45°F]).
3,300 km2 (1,300 sq. mi.) in the arid zone with warm winters (m > 7°C [45°F]).

The major vegetal formations found are:

A. Natural formations

1. Arborscent
Argania spinosa (L.) Skeels (covering about 700,000 ha.); Pistacia atlantica Desf.; Juniperus phoenicea L. et Cerantonia siliqua L.

2. Arbustive
Stipa tenacissima L. (covering about 3 million ha.); Artemisia herba alba Asso.; Withania frutescens (L.) Pauquy; Retama spoerocarpa (L.) Boiss.; Zizyphus lotus (L.) Lamk. Rhus pentaphylla Desf.

B. Plantations

Mainly done with various species of eucalyptus called "desert Eucalyptus:" Eucalyptus torquata Luehmann; Eucalyptus falcata Turcz.; Eucalyptus brockwayi C.A. Gardn. et Eucalyptus astringens Maiden.

The socio-economic impact of this bioclimatic zone is mainly through the following points:

1. It is a vast terrestrial and "aerial" pasture zone for animals such as goats and camels.

2. It is (together with the Sahara zone) the preferred natural habitat for various kinds of game such as gazelle.

3. It is a source for local, national as well as international markets of various products such as alfa paper pulp, argania oil, domestic wood, and foodstuffs.

But it is in the southern part of the country that this arid zone demonstrates its vital importance for man, through:

4. Offering a protection against erosion, thereby stopping the process of desertification.

5. Providing a dwelling place for fixed populations and a well-suited environment for the nomads coming from the desert and looking for water and additional food for their herds.

Morocco is very well aware of the fundamental importance of its arid zone and gives it its utmost attention.

The Moroccan National Forest Inventory was started in 1976 in the northern part of the country, where tree coverage is more dense. It is based on stratified statistical sampling from photo-interpretation, followed by ground inventory at the sampling points.

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[1]Paper for the workshop on Arid Land Resource Inventories, Nov. 30-Dec. 6, 1980, La Paz, Mexico.
[2]Iventaire Forestier National, Casablanca, Morocco.

This national inventory will be extended to the arid zone of the country and will include data on alfa, forest, and other resources.

RESUMEN

Cubriendo aproximadamente 134,000 km^2 (52,300 millas cuadradas), la zona arida bioclimatica comprende alrededor del 15% de el area total de Marruecos. Esta area se divide de la siguiente forma:

41,100 km2 (16,100 millas cuadradas) en la zone arida con inviernos frios (m < 0°C [32°F]).
42,400 km2 (16,500 millas cuadradas) en la zona arida con inviernos frescos (0°C [32°F] < m < 3°C [37°F]).
47,100 km2 (18,400 millas cuadradas) en la zona arida con invierson moderados (3°C [37°F] < m < 7°C [45°F]).
3,300 km2 (1,300 millas cuadradas) en la zona arida con invierson calidos (m > 7°C [45°F]).

Ecología de la Vegetación del Valle de Zapotitlán de las Salinas[1]

J. Alejandro Zavala H. y Silvio Olivieri Barra[2].

RESUMEN.- Por medio de un análisis de Conglomerados se realizó la clasificación de la Vegetación del Valle de Zapotitlán bajo dos planteamientos diferentes: Uno basado en el valor de importancia de las especies registradas y el otro en la presencia o ausencia de las mismas. Ambas clasificaciones son descritas con base a una clasificación fisonómica previa.

INTRODUCCION Y OBJETIVOS.

Una gran controversia sobre la que ha gravitado el desarrollo de los diferentes planteamientos de la Sinecología es acerca de la posibilidad y la forma de dividir en unidades naturales la cubierta vegetal del planeta.

Las dos principales corrientes en cuanto a esta controversia son, por un lado, la que considera la existencia de unidades naturales y sus investigaciones se centran en la definición de estas unidades. Por otra parte tenemos aquellas escuelas que consideran a la clasificación de las comunidades como una herramienta para establecer fronteras de un problema a resolver.

Es aceptado que la mayoría de los trabajos de clasificación se han basado en la experiencia y el criterio subjetivo del investigador dentro de los lineamientos de la escuela que representa. Muchos investigadores han emprendido (sobre todo con el desarrollo de métodos cuantitativos) la búsqueda de una objetividad en sus resultados que le den a la Sinecología una categoría dentro del conocimiento científico; sin embargo, la extrema complejidad de los fenómenos ecológicos aunado al aún incipiente desarrollo de métodos matemáticos aplicables a ellos, han motivado, sobre todo en los últimos años, un gran número de trabajos basados en metodologías muy diversas que aún no se han podido conjuntar dentro de un esquema coherente que permita un desarrollo armónico de esta nueva ciencia.

El presente trabajo, realizado en el interesante valle semiárido de Zapotitlán de las Salinas, constituye el inicio de una serie de estudios con los que se pretende contribuir al conocimiento de la ecología de las zonas semiáridas del país enfatizando el uso de métodos cuantitativos que permitan brindar mayores y más serias posibilidades al manejo de la información que las que dá el mero criterio subjetivo del investigador basado en sus conocimientos, experiencias y concepciones particulares sobre el problema a resolver. El principal objetivo de este trabajo en particular, es el obtener una clasificación de la vegetación del valle de Zapotitlán mediante el uso de un método estadístico de análisis multivariado (Análisis de Conglomerados) evaluada en función de una clasificación previa basada únicamente en la fisonomía de la vegetación apreciada en recorridos de campo y en el análisis de fotografías aéreas. Se pretende que este trabajo conforme un marco de referencia para la realización de estudios futuros.

EL AREA DE ESTUDIO

El área de estudio, con una superficie de 86.74 Km^2, se localiza en el valle de Zapotitlán que se encuentra ubicado dentro de las coordenadas 18° 20' de latitud Norte y 97° 28' de longitud Oeste, enclavado en la sierra del mismo nombre que forma el límite Suroeste del Valle de Tehuacán en el Estado de Puebla.

El clima del Valle de Tehuacán está determinado en gran parte por la Sierra Madre Oriental que detiene los vientos húmedos provenientes del Golfo de México al formar con sus crestas de hasta 2600 m una sombra de lluvia sobre el valle. Aunque parte de la humedad del Golfo atraviesa la sima de la sierra, la precipitación decrece progresivamente alcanzando tan solo 400.2 mm anuales en la Sierra de Zapotitlán. El clima determinado en la estación de Zapotitlán Salinas, corresponde de acuerdo a la clasificación de Koppen modificada por García (1973) a BSohw"(w)(e)g.

Los suelos del valle son muy someros y pedregosos encontrandose Cambisoles Cálcicos, Xerosoles Cálcicos y Litosoles.

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[1]Artículo presentado al Seminario de trabajo "Arid Land Resources Inventories" (La Paz, B.C. Noviembre 30-Diciembre 6, 1980).

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Silvio Olivieri es Jefe del Programa Planeación Ecológica del Uso de la Tierra del INIREB, Xalapa, Veracruz.

METODOLOGIA

Con el fín de tener un primer conocimiento de la vegetación del lugar en base a su composición florística y fisonomía se realizaron recorridos de campo con colecta de ejemplares botánicos y una fotointerpretación de fotografías aéreas escala 1: 25000 del año 1973 para la elaboración de un mapa fisonómico de la vegetación del valle.

En este estudio se pretendía realizar un análisis estadístico de los datos obtenidos por lo que no era conveniente un muestreo preferencial. Lo accidentado del terreno también presentaba serios obstaculos de acceso para realizar muestreos al azar o aún sistemáticos (Orloci, 1975) por lo que se optó por lo siguiente: se localizaron 30 puntos de muestreo distribuídos lo más uniformemente que fué posible con la limitante, además de la posibilidad de acceso, de que no presentase signos evidentes de perturbación humana reciente (fig. 1).

Figura 1.- Localización de los sitios de muestreo

El tipo de muestra utilizado fué un transecto en banda de 50 m de largo por 5 m de ancho subdividido en rectángulos de 10 m^2 cada uno. El tamaño fué determinado analizando el comportamiento de la varianza del número de especies registradas en función del número de submuestras (Sarukhán, 1976).

En cada una de las muestras se midió la altitud, pendiente y orientación del terreno y se tomaron muestras del suelo cada 15 cm para su análisis en el laboratorio. Como variables de vegetación se calcularon la Densidad, Frecuencia y Cobertura absoluta y relativas así como el índice de valor de importancia de Curtis y McIntosh (1951) por medio de un programa de computación en lenguaje PL-1(Zavala, 1980).

Con los valores de importancia obtenidos para cada una de las 108 especies registradas se hizo un archivo en una matriz de 108 x 30. Cuando una especie no se presentaba en una muestra se le asignaba el valor de 0.

Con fines de comparación se elaboró otra base de datos en que se registraba solamente la presencia o ausencia de las especies dándoles valor de 1 y 0 respectivamente.

La clasificación de las 30 muestras fué realizada mediante un Análisis de Conglomerados (Cluster Analysis) con los programas del paquete CLUSTAN de la Universidad de Edimburgo (Whisart, 1978).

El Análisis de Conglomerados es una técnica estadística de análisis multivariado con fines de clasificación que consiste en el agrupamiento de objetos en grupos con alta similaridad interna con respecto a los caracteres que posee cada objeto (Pritchard & Anderson, 1971).

En primer término, la base de datos fué sometida a standarización como recomienda Wishart (1969). A continuación se computó una matriz de similaridad utilizando la distancia Euclidiana al cuadrado como coeficiente de disimilaridad entre las muestras.

El método de aglomeración es el propuesto por Ward (1963). Es un método politético, aglomerativo y jerárquico que combina los dos grupos cuya fusión produce el menor incremento en el error de la suma de cuadrados (Ward, 1963; Orloci, 1967; Whisart, 1969). Los fundamentos matemáticos de este método se pueden encontrar en Ward 1963; Whisart, 1969; 1978; Orloci, 1967; 1975 y Anderberg, 1973.

Con el propósito de obtener un óptimo local para el agrupamiento realizado se utilizó un procedimiento iterativo de reubicación (Whisart, 1978).

RESULTADOS

En base a los recorridos de campo y al análisis de las fotografías aéreas, se elaboró un mapa de la vegetación del valle en el que se reconocen cuatro unidades fisonómicas definidas únicamente por el aspecto dado por las especies más conspicuas (fig. 2). Estas unidades estarían encuadradas dentro del tipo de vegetación denominado matorral xerófilo por Rzedowski (1978) que incluye a todas las comunidades de porte arbustivo, propias de las zonas áridas y semiáridas del país. Las unidades reconocidas son:

1) Matorral nanófilo (Sarukhán et al., 1976). Ocupa un poco más de la mitad de la extensión total del valle. Se establece en las partes bajas y poco accidentadas. Está constituido principalmente por leguminosas arbustivas espinosas entre las cuales se mezclan agaves, cactus no muy grandes y muy pocos árboles bajos con ramas tortuosas. En una gran parte de la extensión que corresponde a esta unidad se han establecido terrenos de cultivo de temporal.

2) Tetechera (Miranda & Hernández, 1963). Son agrupaciones de individuos de cactáceas columnares del género Neobuxbaumia que emergen de entre las especies del matorral nanófilo. Se encuentran en las pendientes de las numerosas colinas que existen dentro del valle.

3) Cardonal (Miranda & Hernández, 1963). Fisonómicamente son muy semejantes a las tetecheras pero la cactácea emergente es *Cephalocereus hoppenstedtii*.

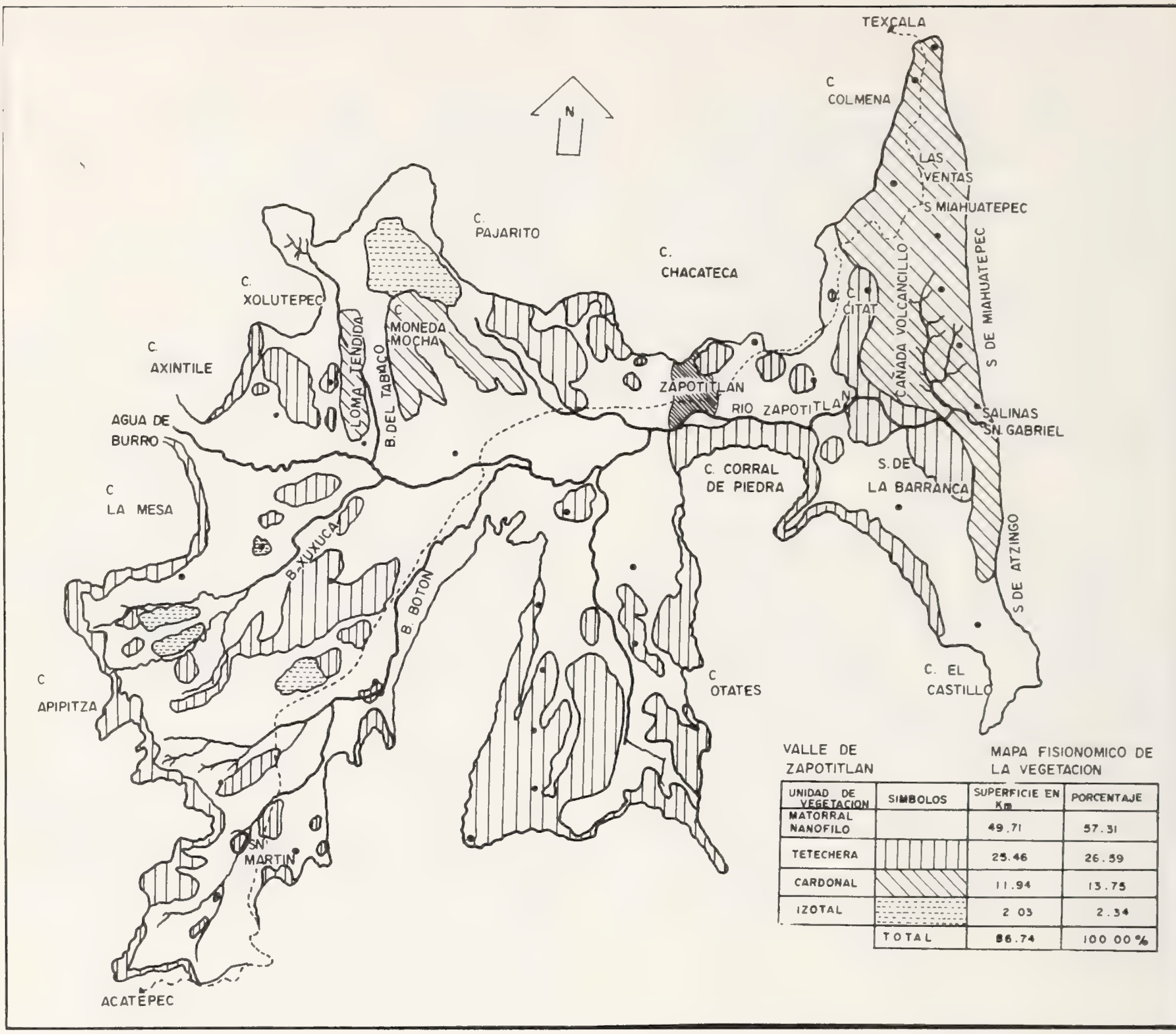

Figura 2.- Mapa que muestra la clasificación fisonómica del Valle de Zapotitlán.

4) Izotal (Miranda & Hernández, 1963). Son agrupaciones de *Beaucarnea gracilis* o de *Yucca periculosa* con una cubierta arbustiva muy rala. Se establece en lomas de pendiente suave.

Esta clasificación representa el punto de vista subjetivo del autor, sin embargo, constituye la única base de que disponemos para comparar e interpretar una pretendida clasificación basada en un análisis más profundo utilizando métodos estadísticos multivariados.

En los recorridos de campo se colectaron 152 especies diferentes agrupadas en 45 familias y 114 géneros distintos de los cuales 27 corresponden a la familia Cactaceae y 17 a la Leguminosae que son las familias más ricas en este aspecto (Zavala, 1980).

De las 108 especies registradas se eliminaron aquellas consideradas como "raras" que se supuso pudieron ser irrelevantes para el análisis de conglomerados. Así, en función de la distribución de los valores para cada especie y de su frecuencia de aparición, fueron eliminadas 74 especies para el agrupamiento basado en el índice de valor de importancia y 63 para el caso de presencia o ausencia.

A cada una de las treinta muestras se le asignó un nombre en función de la unidad fisonómica correspondiente al sitio en que se localizaban. Así tenemos 8 muestras en el matorral nonófilo, 13 en la tetechera, 8 en el cardonal y solamente una en el izotal.

Los grupos obtenidos en función del valor de importancia por el método de Ward y después del proceso de reubicación en el que hubo 9 reacomodos se presentan en la tabla 1 junto con los valores medios de los factores medioambientales medidos.

GRUPO I.- Este grupo se corresponde con el cardonal de la clasificación fisonómica inicial. De los 9 sitios de muestreo que abarca,

Figura 3.- Clasificación de los sitios de muestreo en base al índice de importancia de 34 especies.

seis corresponden con la clasificación fisonómica (fig. 3) dos estaban clasificados como matorral y uno como tetechera.

Las especies con más altos valores de importancia dentro de este grupo son: *Mimosa luisiana*, *Mammillaria collina*, *Mascagnia seleriana*, *Lippia graveolens*, *Zexmenia lantanifolia*, *Echinopterys eglandulosa* y *Hechtia aff. podantha*. Esta unidad esta determinada por plantas de porte arbustivo. La cactácea columnar *Cephalocereus hoppenstedtii* que determina este grupo fisonómico, en ninguno de los casos ocupa uno de los primeros lugares en la jerarquía de cada sitio. Este grupo se presenta en terrenos con pendientes variables (1-19°) con una media de 9.89. La superficie es sumamente pedregosa y el suelo es poco profundo, con una cantidad alta de materia orgánica, fósforo y magnesio.

GRUPO II.-Estaría encuadrado dentro de la tetechera del mapa fisonómico. Comprende quince sitios de los cuales once corresponden a la tetechera de la primera clasificación, tres al matorral nanófilo, y uno al izotal. Las especies que caracterizan este grupo son *Mimosa luisiana*, Compositae 02, *Cordia cylindrostachya*, *Neobuxbaumia tetetzo*, *Ruellia sp.* y *Mammillaria collina*. Este grupo también está caracterizado por especies arbustivas, con la particularidad de que en este caso la cactácea columnar Neobuxbaumia tetetzo que determina la fisonomía de las tetecheras en la clasificación inicial, si se encuentra entre las especies con más alto valor de importancia. Este grupo, al igual que el cardonal, se encuentra en terrenos muy accidentados y pedregosos con pendientes que van de 5° a 26° con una media de 9. La cantidad de materia orgánica y fósforo es mayor que en el cardonal y menor la de magnesio. También presenta altas concentraciones de sodio y calcio.

GRUPO III.-Es análogo al matorral nanófilo de la clasificación fisonómica. De las 5 muestras que incluye, tres coinciden con la clasificación inicial y las dos restantes estaban encuadradas dentro dle cardonal. Las especies que caracterizan este grupo son *Zexmenia lantanifolia*, *Castela tortuosa*, *Cercidium praecox*, *Caesalpinia melanadenia* y *Mammillaria collina*, todas ellas de porte arbustivo.

Este grupo se encuentra en terrenos más o menos planos con una pendiente media de 3°. El suelo es poco pedregoso y un poco más profundo que en los dos grupos anteriores con una cantidad de materia orgánica relativamente baja y alta la de sodio y potasio.

Tabla 1.- Medias del valor de importancia de 34 especies y de los factores medioambientales para los 4 grupos obtenidos en la clasificación.

GRUPO	I	II	III	IV
No. de muestras que abarca	9	15	5	1
ESPECIES %:				
Lippia graveolens	6.03	3.79	0.47	15.80
Hechtia aff. podantha	5.15	0.57	0.56	1.36
Aeschynomene americana	2.54	3.03	0.89	3.37
Bursera arida	1.83	0.14	0.00	0.00
Agave kerchovei	4.19	0.82	0.13	0.45
Castela tortuosa	1.76	0.31	8.99	0.00
Mimosa luisiana	9.39	16.84	2.14	4.73
Cephalocereus hoppenstedtii	1.88	0.06	0.90	0.00
Mascagnia seleriana	7.28	1.77	1.57	0.00
Mammillaria collina	8.00	4.16	5.43	3.01
Pedilanthus aphyllus	3.21	0.48	3.79	0.00
Caesalpinia melanadenia	2.68	1.16	6.54	0.00
Ferocactus recurvus	0.53	0.60	2.27	0.85
Ruellia sp.	2.32	4.53	1.76	1.46
Echinopterys eglandulosa	5.19	2.31	1.94	21.63
Cercidium praecox	0.00	2.01	7.07	0.00
Eysenhardtia polystachya	0.31	2.21	0.29	1.61
Opuntia macdougaliana	0.32	1.88	0.44	9.83
Agave marmorata	0.87	2.50	0.19	0.00
Ayenia fruticosa	0.77	0.36	0.96	0.00
Cordia cylindrostachya	2.09	5.59	0.47	12.67
Neobuxbaumia tetetzo	0.00	4.90	0.00	4.27
COMPOSITAE 1	2.13	1.01	0.12	1.61
Ipomoea arborescens	1.08	1.02	0.36	0.00
Acacia constricta	2.53	2.86	3.70	0.53
Zexmenia lantanifolia	5.85	2.89	14.57	2.98
Opuntia tunicata	0.09	0.02	1.79	0.00
Selloa glutinosa	0.00	0.60	1.51	0.40
Opuntia pilifera	0.00	3.31	0.92	0.00
Prosopis laevigata	0.15	2.18	4.17	0.00
Lantana sp.	0.83	3.01	0.63	3.59
Coryphantha pallida	1.86	1.22	0.34	1.97
COMPOSITAE 2	0.89	7.52	0.11	3.29
Mammillaria carnea	0.14	1.82	3.76	0.35
FACTORES MEDIOAMBIENTALES:				
Altitud (m.s.n.m.)	1492.78	1491.33	1437.00	1520.00
Pendiente (°)	9.89	9.00	3.00	4.00
SUELOS:				
Profundidad (cm)	31.33	28.00	41.60	30.00
Arcilla (%)	35.42	33.07	31.83	33.24
Arena (%)	20.48	23.06	20.12	20.60
Limo (%)	44.88	43.02	48.05	46.16
Materia orgánica (%)	4.62	4.63	2.46	5.00
Cap. Int. Cat. meq/100g	33.34	37.10	25.34	38.50
pH	8.06	7.99	8.10	8.20
Sodio (ppm)	69.61	115.86	356.42	96.80
Potasio (ppm)	232.89	223.37	327.00	252.00
Calcio (ppm)	5992.11	7183.53	5325.00	6260.00
Magnesio (ppm)	326.56	235.28	285.80	221.00
Fósforo (ppm)	15.89	17.73	14.66	13.00

GRUPO IV.- Este grupo incluye un solo sitio y puede ser considerado como "raro" entre la población ya que fisonómicamente y en cuanto a la jerarquía de las especies dada por su valor de importancia correspondería al grupo de tetecheras, sin embargo, el alto valor de importancia de *Echinopterys eglandulosa* y *Opuntia macdougaliana* hace que sea colocado como un grupo aparte. Los parámetros medioambientales medidos en este grupo se encuadran dentro del rango de variación de los mismos para las tetecheras.

Dentro de los cuatro grupos se encontraron variaciones altitudinales que comprenden el rango de la población total. En cuanto al suelo, en general se presenta una textura moderadamente fina del tipo migajón arcilloso. Los suelos son alcalinos (pH-8) y un contenido alto de materia orgánica, fósforo y nutrientes, generalmente son muy pedregosos y con una capa calichosa a poca profundidad.

Los grupos obtenidos utilizando atributos de presencia-ausencia se presentan en la tabla 2. Mediante el proceso de reubicación se reacomodaron cinco sitios de muestreo después del agrupamiento por el método de ward.

GRUPO A.- Es análogo al cardonal de la clasificación fisonómica inicial. De las nueve muestras que abarca (fig. 4) siete corresponden a la designación fisonómica, una estaba considerada como matorral nanófilo y la última como tetechera.

Las especies que caracterizan a este grupo con un porcentaje de aparición mayor del 90% son *Mimosa luisiana*, *Cephalocereus hoppenstedtii*, *Mascagnia seleriana*, *Mammillaria collina*, *Ruellia sp.*, *Ecinopterys eglandulosa* además de *Pedilanthus aphyllus* y *Cassia pringlei* que tienen un porcentaje

Figura 4.- Clasificación de los sitios de muestreo en base a la presencia de 45 especies.

Tabla 2.- Porcentaje de aparición de 45 especies y medias de los factores medioambientales para los 4 grupos obtenidos utilizando datos de presencia-ausencia.

GRUPO	A	B	C	D
No.de muestras que abarca	9	16	4	1
ESPECIES %:				
Lippia graveolens	77.8	81.3	0.0	100.0
Hechtia aff. podantha	66.7	62.5	50.0	0.0
Aeschynomene americana	77.8	100.0	25.0	100.0
Bursera arida	66.7	18.8	0.0	0.0
Agave kerchovei	55.6	25.0	25.0	100.0
Castela tortuosa	55.6	18.8	100.0	0.0
Mimosa luisiana	100.0	100.0	0.0	100.0
Cephalocereus hoppenstedtii	100.0	18.8	0.0	0.0
Mascagnia seleriana	100.0	56.3	0.0	100.0
Mammillaria collina	100.0	93.8	75.0	0.0
Pedilanthus aphyllus	88.9	25.0	50.0	0.0
Caesalpinia melanadenia	88.9	37.5	75.0	100.0
Ferocactus recurvus	55.6	81.3	50.0	100.0
Ruellia sp.	100.0	93.8	75.0	100.0
Echinopterys eglandulosa	100.0	68.8	50.0	100.0
Cassia pringlei	55.6	18.6	0.0	0.0
Cercidium praecox	22.2	31.3	100.0	0.0
Eysenhardtia polystachya	22.2	93.8	100.0	0.0
Opuntia macdougaliana	0.0	56.3	50.0	0.0
Agave marmorata	11.1	43.8	75.0	0.0
Ayenia fruticosa	55.6	25.0	75.0	0.0
Cordia cylindrostachya	55.6	100.0	75.0	100.0
Neobuxbaumia tetetzo	0.0	68.8	0.0	0.0
COMPOSITAE 01	44.4	43.8	0.0	0.0
Ipomoea arborescens	55.6	81.3	0.0	0.0
Acacia constricta	44.4	68.8	100.0	100.0
Zexmenia lantanifolia	88.9	50.0	100.0	0.0
Opuntia tunicata	22.2	6.3	75.0	0.0
Selloa glutinosa	0.0	31.3	100.0	100.0
Opuntia pilifera	11.1	56.3	50.0	100.0
Myrtillocactus geometrizans	33.3	25.0	75.0	100.0
Prosopis laevigata	11.1	50.0	100.0	100.0
Lantana sp.	55.6	81.3	100.0	100.0
Coryphantha pallida	66.7	75.0	75.0	0.0
COMPOSITAE 02	11.1	87.5	75.0	100.0
Mammillaria carnea	44.4	68.8	75.0	0.0
Croton ciliato-glandulosus	11.1	18.8	25.0	100.0
Beaucarnea gracilis	22.2	6.3	0.0	100.0
Bouvardia erecta	11.1	6.3	0.0	100.0
Bursera sp.	77.8	0.0	0.0	0.0
Ceiba parvifolia	0.0	12.5	0.0	0.0
Neobuxbaumia mezcalaensis	0.0	6.3	0.0	0.0
Dasylirion lucidum	11.1	12.5	0.0	0.0
Pseudosmodingium multifolium	11.1	12.5	0.0	0.0
Bursera morelensis	11.1	0.0	0.0	0.0
FACTORES MEDIOAMBIENTALES:				
Altitud (m.s.n.m.)	1467.22	1489.38	1486.25	[illegible]
Pendiente (°)	10.67	8.88	0.75	15.0
SUELOS:				
Profundidad (cm)	32.22	26.56	[illegible]	[illegible]
Arcilla (%)	35.36	35.46	24.44	15.94
Arena (%)	18.88	20.71	[illegible]	[illegible]
Limo (%)	46.05	43.02	[illegible]	[illegible]
Materia orgánica (%)	[illegible]	4.40	2.50	[illegible]
Cap. Int. Cat. meq/100g	28.40	37.34	31.05	[illegible]
pH	8.07	8.04	[illegible]	[illegible]
Sodio (ppm)	[illegible]	92.99	167.45	74.30
Potasio (ppm)	250.44	[illegible]	352.50	405.00
Calcio (ppm)	5789.44	6395.17	5514.75	10900.00
Magnesio (ppm)	771.00	[illegible]	458.50	159.00
Fósforo (ppm)	15.60	15.56	21.13	21.3

de aparición alto en este grupo y bajo en los otros. Esta composición vegetal concuerda con la apreciación fisonómica.

Este grupo se encuentra en terrenos muy accidentados con variaciones de pendiente de 3° a 19° con una media de 10.67. La superficie del suelo es muy pedregosa y éste es poco profundo con una elevada cantidad de materia orgánica, fósforo, sodio y magnesio. La textura es moderadamente fina del tipo migajón arcilloso-limoso.

GRUPO B.- Este grupo corresponde a la tetechera de la clasificación fisonómica. De los 16 sitios que comprende, doce concuerdan con la agrupación inicial, tres eran considerados dentro del matorral nanófilo y uno como cardonal.

Las especies características de este grupo son *Aeschynomene americana*, *Mimosa luisiana*, *Cordia cylindrostachya*, *Mammillaria collina*, *Ruellia sp.* *Eysenhardtia polystachya* además de *Neobuxbaumia tetetzo* que solamente aparece en este grupo aunque no en todos los muestreos que lo integran. Este grupo se establece en terrenos muy accidentados con una pendiente media de 8.88° y una superficie muy pedregosa. El suelo presenta una textura moderadamente fina del tipo migajón arcilloso, es muy somero y con altas cantidades de fósforo y materia orgánica y relativamente bajo contenido de sodio y magnesio.

GRUPO C.- Es análogo a la unidad fisonómica del matorral nanófilo. Comprende cuatro sitios de muestreo. Todos ellos considerados inicialmente como matorrales. Las especies que caracterizan a esta unidad son *Castela tortuosa*, *Cercidium praecox*, *Eysenhardtia polystachya*, *Zexmenia lantanifolia*, *Selloa glutinosa*, *Prosopis laevigata*, *Lantana sp.*, *Agave marmorata*, *Opuntia tunicata* y *Myrtillocactus geometrizans*. Todas estas especies son de porte arbustivo salvo la última que es una cactácea candelabriforme baja (2-5 m). Los sitios que constituye esta unidad se establecen en terrenos planos con suelo un poco menos somero y pedregoso que el de los grupos anteriores. Estos suelos presentan una textura media del tipo migajón limoso con una cantidad relativamente baja de materia orgánica y altas concentraciones de fósforo, sodio y potasio.

GRUPO D.- Está constituído por un sólo sitio que corresponde al único izotal muestreado de acuerdo a la clasificación fisonómica. Debido a que todas las especies que aparecen en este grupo tienen un porcentaje de aparición de 100% solamente se considera como especies características a aquellas que al menos en dos de los otros tres grupos tienen un porcentaje de aparición menor del 35%. Estas especies son *Beaucarnea gracilis*, *Bouvardia erecta*, *Croton ciliato-glandulosus*, *Myrtillocactus geometrizans* y *Agave kerchovei*. De ellas, *B. gracilis* es la que determina la unidad fisonómica izotal. La única muestra se encuentra en un terreno con pendiente de 15°. El suelo es somero con una textura moderadamente fina del tipo migajón arenoso con altos contenidos de materia orgánica, fósforo, calcio y potasio y baja cantidad de sodio y magnesio.

Al igual que en la clasificación basada en valores de importancia, dentro de estos cuatro se presentan variaciones altitudinales que comprenden el rango de la población total. Los suelos son alcalinos con un alto contenido de materia orgánica, fósforo y nutrientes. Generalmente son pedregosos y poco profundos con una capa calichosa.

DISCUSION

Rigurosamente hablando, el método de muestreo utilizado es válido únicamente para el registro de atributos de presencia de las especies, siendo éste un problema de la mayoría de los estudios sinecológicos en los que se determina el área a muestrear en base a una curva área-especies o bién en base a tamaños standar determinados empíricamente que son aceptados más o menos universalmente y que dependen del tipo de vegetación bajo estudio (Mueller Dombois & Ellenberg, 1974). Sin embargo, el intentar buscar un tamaño de muestra teóricamente óptimo hubiera conducido a una inversión de tiempo y dinero antieconómico y contra la idea del muestreo limitado (McIntosh, 1978).

De acuerdo con Grime (1979) la mayoría de las muestras de vegetación incluyen un mosaico complejo de micro-hábitats que surgen de factores tales como variaciones edáficas, interacciones entre microtopografía y clima, depredación selectiva, perturbación local del suelo y redistribución de nutrientes por animales, además de diferencias espaciales que surgen de la actividad de las plantas mismas, como pueden ser variación en la disponibilidad de nutrientes y de agua, acumulación de "litter" y toxinas orgánicas y modificación de la microflora del suelo. No sería raro esperar que diferencias en características como textura del suelo, status de nutrientes minerales, desecación y grado de interferencia luminosa por estratos superiores serían suficientes para el establecimiento de diferentes especies.

Es claro que dentro del valle de Zapotitlán las variaciones medioambientales se dan a pequeña escala y el problema estriba en identificar las circunstancias en que esta variación es suficiente para iniciar o mantener las condiciones favorables para la coexistencia de especies diferentes y el establecimiento de distintas comunidades vegetales.

Las dos diferentes estrategias utilizadas para la realización de la clasificación, en base al valor de importancia y a la presencia o ausencia de las especies, tienen que ver en cierto modo con la clasificación por dominantes de las tradiciones rusa, inglesa y americana y la clasificación por constancia de especies de la tradición del Norte de Europa respectivamente (Whittaker, 1962).

Revisando las dos clasificaciones obtenidas se pueden apreciar coincidencias fundamentales en los tres primeros grupos de cada una,pues las especies dominantes en un caso y las constantes en el otro son esencialmente las mismas, además de que estos tres grupos, en ambos casos, coinciden con el cardonal, tetechera y matorral de la clasificación fisonómica inicial.

Por lo que respecta a la estabilidad de la clasificación dada por el número de reubicaciones necesarias para la obtención del óptimo local de agrupamiento y a la coincidencia con la clasificación fisonómica inicial, el agrupamiento por atributos de presencia-ausencia parece ser el más adecuado, sin embargo, los resultados obtenidos en el agrupamiento por valores de importancia no nos dan elementos para rechazarlo totalmente, sobre todo considerando la información que el uso de índices de importanica puede dar sobre el papel que cada es-

pecie juega dentro de la comunidad. Así, podemos decir que cuando se necesita una clasificación con fines únicamente de inventario en trabajos en los que la economía en el muestreo sea un factor limitante, es suficiente registrar únicamente la presencia de las especies en los muestreos para obtener una buena clasificación, pero si se pretende inferir aspectos más finos de la ecología de las comunidades, es deseable la búsqueda de índices que digan algo acerca de la función de las especies en la comunidad.

Los resultados obtenidos no nos proporcionan una visión objetiva de la vegetación del valle de Zapotitlán pero sí nos dan un marco de referencia para la realización de otros estudios y nos revelan una serie de posibilidades para el manejo de los datos y estrategias de estudio a seguir.

Se plantea para el futuro el uso de métodos más rigurosos para la evaluación de la clasificación obtenida, como puede ser un análisis Discriminante (Del Moral, 1975), así como el uso de métodos de ordenación que permitan llegar a identificar los factores medioambientales que determinan la variación entre los distintos sitios.

También sería muy interesante ampliar el número de sitios de muestreo para abarcar todo el valle incluyendo el gradiente altitudinal que se presenta en los grandes cerros que forman sus paredes así como aplicar la misma metodología (tratando de mejorarla) en otras zonas semiáridas con el fin de poder llegar a la implementación de un método de muestreo y análisis aplicable a este tipo de vegetación que sea rápido, eficiente y barato.

El valle de Zapotitlán es un lugar ideal para la realización de estudios biológicos en zonas semiáridas que tan poco conocemos para lo cual es necesario contar con un área de investigación protegida contra la perturbación humana que posibilite la continuidad y seguridad de los trabajos sin olvidar la necesaria interrelación con sus habitantes y su problemática socio-económica.

SUMMARY

This work is the begining of a series of ecological studies at the interesting Valley of Zapotitlán de las Salinas, Puebla; with emphasis in the use of cuantitative methods of multivariate analysis that could lead us if not to an objective knowledge of the vegetation, at least to find more serious posibilities on the management of the information than the ones given only by the subjective criteria of the ecologist based on his own knowledge, background, and conceptions of the problem to solve.

The classification of vegetation is not the search for natural units, but the delimitation of logic entities of study in which more specialized future studies could be based.

A study area of 86.74 Km^2 was delimited and thirty samples of 250 m^2 each were made recording values of cover, density and frecuency for the plant species. Also environmental characteristics of each site were considered.

Using a multivariate statistical method of Cluster Analysis two classifications were obtained based on two different criteria: one that considers the presence or absence of the species on each site; and the second based on the dominance of each species according to Curtis & McIntosh's Importance Value Index (1951) that in some way would express the roll of each species in the community.

These two groupings are compared based on a previous classification (only physonomical) made on successive surveys on the zone and on aereal photographs.

The groups obtained on each classification are described using the environmental characteristics cuantified.

Finally, the necesity of more exhaustive studies on the zone and also of its preservation are pointed out.

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Classifying and Characterizing Natural Vegetation on a Regional Basis with Landsat MSS Data[1]

Kirk C. McDaniel and Robert H. Haas[2]

Abstract.--Landsat multispectral scanner imagery and digital data are suitable for classifying and quantifying natural vegetation conditions on a regional basis. Stratifying relatively uniform vegetation-soil systems on Landsat imagery is the first step in employing Landsat MSS data for regional vegetation survey programs. The second step is to establish the functional relationships of Landsat derived reflectance models to various vegetation parameters found in each stratified vegetation-soil system being inventoried.

INTRODUCTION

Vegetation surveys provide basic information required for better range and forest management. Most naturally vegetated areas on earth have only partially been described and are rarely surveyed on a regular basis. The ability to rapidly delineate vegetation boundaries on space imagery and to quantitatively assess vegetation conditions within the mapped boundaries represents a realistic use of Landsat technology.

Before the Landsat-1 satellite was launched, little was known of its actual potential and subsequent impact on natural resource management. The benefits were soon realized when ". . . the satellite began returning pictures within three days (after launching). The pictures were of excellent quality, and could be combined into the equivalent of false color infrared film photography. The first geologic sketch map, show many features interpreted as unmapped faults in the California Coast Ranges, was finished by Paul D. Lowman, just ten days after launch . . ." (Recounted by Fischer 1975, from Lowman 1972). Since this time, thousands of reports and maps have been produced demonstrating the usefulness of Landsat imagery for natural resource management.

The Landsat images are especially applicable for mapping earth surface features, while computer data can provide more in-depth quantitative information not directly obtainable from the images themselves. Together, Landsat imagery and digital data products are a useful tool for describing natural vegetation of a regional basis (fig. 1).

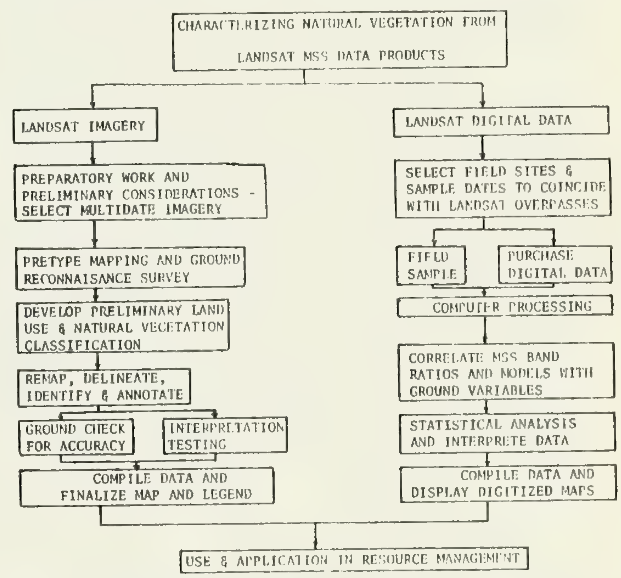

Fig. 1. Flow diagram showing major steps involved in the use of Landsat imagery for mapping purposes, and Landsat digital data for quantifying field measured vegetation parameters.

The image/data flexibility offered by the Landsat Multispectral Scanner has not yet been fully exploited. However, research has shown the appropriate path to follow for use of this information in the inventory and monitoring of natural vegetation conditions.

Among the more important advantages of employing a Landsat image/data analysis approach are:

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(1) Landsat data provides a suitable format for describing earth surface features. Landsat color composite imagery obtained from different dates and image scales, permits the mapping and classification of specific land use and natural vegetation landscapes. The vegetation types that are mapped are related to image signatures and are ecologically based. Each vegetation type classified can be given a name and described using phytosociological principles. Analyses of Landsat digital data can provide a quantitative assessment of plant growth conditions within the vegetation type. The quantitative and qualitative information obtained can provide important data for earth resource analysis systems.

(2) Landsat imagery provides an approach for identifying key sites. Vegetation-soil systems which are identified on the Landsat imagery denote areas with similar natural productivity potentials. The plants are the visible, biological evidence which reflect the influence of soil, landform and climatic conditions and are most relevant for differtiating vegetation types. The vegetation type, correctly defined phytosociologically is indicative of unique "site" conditions repeated across the landscape. Selected key sites within each vegetation type can be monitored to characterize lands with analogous effective environments and production potentials.

(3) Landsat data enables stratification for efficient subsampling. Mapping upon Landsat imagery using "signatures" as a basis for stratification provides a meaningful method for eliminating excessive variation within a region. Isolating unwanted ground subjects by image analysis can lead to more efficient field and computer sampling procedures. Whereas image analysis involves the breakdown of relatively homogeneous units, digital data analysis can provide a more in-depth and refined analysis within these units. Additionally, sites studied intensively through computer techniques can later be recombined with other key sites to provide a quantitative description of larger areas.

(4) Landsat provides an information base for future resource management. Landsat data products can provide base maps upon which resource information accumulated over time can be updated and summarized. These data enable the resource manager to be continually appraised of a present management needs in areas under his jurisdiction. This information serves a useful purpose as an aid to land resource planning and to the decision making process.

(5) Landsat data provides a high degree of flexibility for management purposes. Flexibility is found in both the general nature of surveys conducted with the imagery, and with the intensive quantitative assessments taken from digital data. An overall inventory and analysis can start on broad regional areas to identify the general nature of the vegetation, soils and landforms in the region. Intensive digital measurements can later be taken within selected sites to upgrade management information needs. The information from the image/data analysis can be interpreted in many ways and at different levels depending on the intensity of management decisions being made. Because the inventory includes ecological based information, flexibility of interpretation is maximized.

(6) Landsat provides easily understood information. The wealth of information generated from a Landsat image/data analysis can be displayed in a manner which can easily be understood. This is not to say that generating these products is easy, however. Procedures currently available, particularly those involving the computer, are somewhat complex, time consuming, and expensive. The relative cost per unit of information needs further evaluation. Information displayed in map form from the imagery can include descriptive legends that are logical, concise, and consistent with ecological and photo interpretation principles. Digital data provides information amenable to statistical testing. Sound biological information which can be related to field and digital data may be displayed in easy to read computer map form.

(7) Landsat will provide timely information through the future. Plans for launching new earth orbiting satellites similar to the Landsat-1, -2, and -3 systems are planned through the remainder of this decade. The Landsat-1 satellite became inoperable in early January, 1978. According to Doyle (1978) another Landsat satellite is scheduled for launching in 1981 and additional satellites will be launched in the future as time and need arises. The future of more refined earth observation satellites with better remote sensing capabilities is projected. The present time consuming man-interactive steps required to handle Landsat image/data products is also certain to be shortened. As man continues to develop this new technology, the information it provides for natural resource management should continue to grow rather than diminish in the future.

NATURAL VEGETATION CLASSIFICATION FROM LANDSAT IMAGERY

Attempts to classify natural vegetation types from Landsat imagery have for the most part been general. This is primarily because natural vegetation has been treated as a generalized category within larger land-use classification systems. (Anderson et al. 1972; Poulton 1972; and McDaniel 1974). A notable exception to generalized natural vegetation classification is reported by Schrumpf, Johnson and Mouat (1973). They developed a natural

vegetation classification for southern Arizona which described 31 vegetation types throughout the region. In developing their classification system there was considerable ground work prior to visual photo interpretation from space (Apollo, Gemini, and Landsat-1) and high flight aerial photography. The natural vegetation classification scheme designed by Schrumpf, Johnson and Mouat (1973) was not structured by a hierarchical arrangement, but they felt it could easily be adapted to fit more generalized land-use and natural vegetation legend systems.

Hironaka et al. (1973) used Landsat imagery to successfully map semi-arid vegetation in southern Idaho. Single waveband black and white frames and color-enhanced imagery acquired from four seasonal Landsat overpasses were used for visual mapping purposes. Natural vegetation landscapes were delineated by placing heavy reliance on color, density, texture, shape, and pattern differences between vegetation subjects. They noted additional mapping information was available when the same scene was viewed during different stages of vegetation growth and activity.

Morain et al. (1977) compiled a map of the vegetation and land use patterns in New Mexico insofar as they could be observed or inferred from Landsat imagery. The map was prepared directly from 24 separate Landsat color composite transparencies at the scale of 1:1,000,000. Initial interpretations were made by drawing boundary lines on mylar sheets placed over the images, then combining the information to create a mosaic of the State of New Mexico. Ground truth trips were taken to check map accuracy and to name vegetation types. The vegetation types named by Morain et al. (1977) were correlated with the national land use and land cover classification scheme given in U.S.G.S. Circular 964 (Anderson et al. 1976).

In most studies involving Landsat, there has rarely been an attempt to map vegetation patterns without collecting supportive ground information. Image signatures are used to delineate vegetation boundaries but the actual vegetation types must be determined in the field (Morain et al. 1977). When comparing maps drawn from space imagery with actual field conditions, a ground reconnaissance trip is usually taken to establish subject-image relationships. There are numerous approaches available to describe and name the vegetation encountered along a ground reconnaissance route, each method having its own set of merits (Mueller-Dombois and Ellenberg 1974).

When developing a vegetation classification system compatible for use with Landsat imagery it is often necessary, because of resolution limitations, to represent only the prevailing or major existing vegetation types and to omit others (Morain et al. 1977). In this instance, smaller classification units are omitted and absorbed as inclusions within the boundaries of larger units. To describe these broad vegetation units Fosberg (1961) suggested the classification be based on physiognomic, structural, and floristic characteristics of the vegetation. When the classification is based on floristic criteria then

> . . . the problem of separating vegetation units can be studied and resolved after species list of all sample stands are transferred into a single table. Such a table, showing the floristic information of all releves under comparison, is conveniently referred to as a synthesis (or association) table. A synthesis table, in addition to offering an aid in classification, often reveals information that was not realized during the field work. Moreover, a synthesis table serves as a means of documenting the floristic information of a vegetation study . . . (Mueller-Dombois and Ellenberg 1974).

This approach is particularly desirable for describing natural vegetation in conjunction with remote sensing because the present vegetation conforming to image signatures is being described. The approach does not require a thorough knowledge of successional seres and climax representatives as a prerequisite to classification (Johnson 1974).

For verifying a final mapping effort against actual field conditions, a ground truth trip is usually taken where ". . . a list of potential verification sites are drawn randomly, and a visit is made to each site to determine subject-image characteristics . . ." (Hord and Brooner 1976). Data from the ground truth trip can be used to determine map accuracy.

When a final map and classification system is prepared, photo interpretation tests can be given to determine the ease of use and repetitive accuracy of the classification scheme (Johnson 1974). Photo interpretation tests provide insight into the role of the interpreter and clarity of the classification system. One means of objectively evaluating an interpretation test is to arrange data into tables showing comparisons between correct and incorrect interpretations, and errors of omission and commission. Ross (1973) explains omission errors as correct responses which are left out of a particular group; and commission errors as incorrect responses which are erroneously included in a group. These tables are most useful for observing accuracy within and among legend categories as well as total interpretative accuracy.

ASSESSING NATURAL VEGETATION CONDITIONS FROM LANDSAT MSS DIGITAL DATA

Several remote sensor packages were originally equipped aboard the Landsat-1 and Landsat-2 satellites, but the broad band multi-spectral scanner system (MSS) has received the greatest use. The MSS system scans the earth's surface from east to west within a 185 kilometer strip as the satellite travels in a near-polar, sun synchronous

orbit about 920 kilometers above the earth. The earth is scanned by an oscillating flat mirror which reflects radiant energy onto an array of twenty-four detectors. The instantaneous field of view of each detector subtends a 79 x 79 meter area on the ground. The multi-spectral scanner images the surface of the earth in four spectral bands simultaneously utilizing the same optical system (ERTS-1 Data User Handbook 1972). These spectral bands refer to energy detected by the multispectral scanner in the 0.5 to 1.1 micrometer region of the electromagnetic spectrum. The multispectral scanning system is divided into the following four spectral bands and color regions:

Band 4	0.5-0.6 micrometer	Green
Band 5	0.6-0.7 micrometer	Red
Band 6	0.7-0.8 micrometer	Near infrared
Band 7	0.8-1.1 micrometer	Near infrared

Each of these spectral bands provide unique and different information about vegetation conditions because of differences in the amount of reflected energy viewed in each channel. Reflectance from a plant under natural conditions is an integrated response from the plant's reproductive structures, leaves, branches, dew, dust, and innumerable other factors; most, however, originate from the leaves (Janza 1975). The importance of the leaves' effect on reflectance lies in the heterogeneous characteristics of the structure itself and other plant attributes such as maturation, yield, and ground cover.

Foliage of green plants differentially absorbs and reflect energy in the visible (0.5-0.7 um) and near infrared (0.7-1.1 um) regions of the spectra measured by Landsat (Rouse et al. 1974). The theoretical relationship between percent reflectance of energy from green and standing dormant herbaceous vegetation and soil in each of Landsat MSS spectral bands is illustrated in Fig. 2 (adapted from data

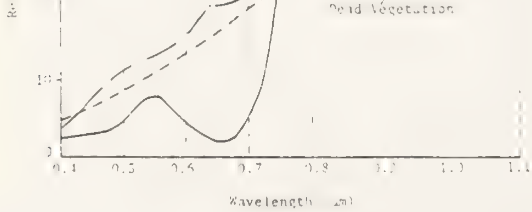

Figure 2. Reflectance of soil, green vegetation, and dead or dormant vegetation. Adapted from data by Coulson et al. 1965; Pearson and Miller 1972; and Deering and Haas 1977.

provided by Coulson et al. 1965; Pearson and Miller 1972; and Deering and Haas 1978). The red band (MSS Band 5) energy is strongly absorbed by chlorophylls in dense green vegetation, whereas near-infrared band (MSS Bands 6 and 7) energy is strongly reflected by the mesophyll portion of the leaf (Gates et al. 1965). The magnitude of differences between the red band and near-infrared bands increases as vegetation becomes "greener"; and conversely becomes less as vegetation becomes dormant or dead. Several investigators have taken advantage of the spectral differences between MSS bands by developing ratios and "vegetation index" models to be related to vegetation conditions (Carneggie et al. 1974; Maxwell and Johnson 1974; Rouse et al. 1974; Thomas 1975; Kauth and Thomas 1976; Richardson and Wiegand 1977; Deering et al. 1977).

Carneggie et al. (1974) found repetitive seasonal data coverage from Landsat to be useful for monitoring range condition and phenology within the annual grasslands of California. They used Landsat MSS digital data extracted by computer to quantify the occurrence of germination, peak foliage production, and period of drying. This was accomplished using a wavelength ratio of Band 7 over Band 5 and relating the rise or fall in the value of the ratio to field conditions.

Maxwell and Johnson (1974) used Landsat MSS digital data to group and display range condition and green biomass classes. Their approach of ratioing Band 7 to Band 5 to separate classes was similar to that of Carneggie et al. (1974). In a subsequent study, Maxwell (1976), used this same ratio to create computer maps which separated standing crop biomass of rangeland into 500 lb/acre increment classes.

Rouse et al. (1973) used Landsat MSS digital data to study the vernal advancement and retrogradation of natural vegetation throughout the Great Plains Corridor. After testing various MSS band ratios they derived a "transformed vegetation index" model using the normalized difference of Band 7 and Band 5 as follows:

$$\text{TV17} = \sqrt{\frac{\text{Band 7} - \text{Band 5}}{\text{Band 7} + \text{Band 5}} + 0.5}$$

The model, which corrected for atmospheric and illumination conditions to reduce temporal data variation, was successfully used to monitor the "green wave effect" of seasonal vegetation growth. By incorporating data on weather and soil moisture conditions, Rouse et al. (1974) used regression analysis to develop a new model combining Band 6 and Band 5 to estimate green standing biomass production within a homogeneous grassland area on the Throckmorton Experimental Ranch in northcentral Texas. This model, called the transformed vegetation index model "6" or "TVI6" was calculated as follows:

$$\text{TVI6} = \sqrt{\frac{\text{Band 6} - \text{Band 5}}{\text{Band 6} + \text{Band 5}} + 0.5}$$

Rouse et al. (1974) reported the TVI6 model to be highly correlated to green herbaceous standing biomass on the Throckmorton Ranch. Deering et al. (1977) in a follow on study also related the TVI6 model to green biomass on the Throckmorton Ranch but his results were less conclusive. In the follow on study Deering gave two reasons for results he felt were poorer than what could normally be expected. First, during the year of his study there was an abnormally high infestation of annual broomweed masking the production of other herbaceous plants. Thus, the TVI6 model and green biomass estimates were poorly correlated. A second problem was an incompleted data set because of cloud cover during Landsat overpasses and generally inadequate field data. Despite these problems, Deering et al. (1977) concluded that the TVI6 model was suitable for measuring green vegetation conditions. He recommended future studies to examine the relationship of the TVI6 model with range scene components other than green biomass, such as total biomass and ground cover.

Two vegetation index models derived from Landsat digital data were extensively used in the Large Area Crop Inventory Experiment (LACIE) at the Johnson Spacecraft Center, Houston, Texas, to ". . . describe important crop phenomena concerning soil background and green development" (Richardson and Wiegand 1977). The models developed by Kauth and Thomas (1976) use transformed information within all 4 MSS bands to derive a soil brightness index (SBI) model and a green vegetation index (GVI) model:

$$\text{SBI} = 0.433 \text{ Band } 4 + 0.632 \text{ Band } 5 + 0.586 \text{ Band } 6 + 0.264 \text{ Band } 7,$$

and

$$\text{GVI} = -0.290 \text{ Band } 4 - 0.562 \text{ Band } 5 + 0.600 \text{ Band } 6 + 0.491 \text{ Band } 7.$$

Richardson and Wiegand (1977) compared the TVI, TVI6, SBI and GVI models and three models they derived with ground measured parameters taken from sorghum cropland in South Texas. The models they derived were as follows:

Perpendicular Vegetation Index

$$\text{PVI} = (\text{Rgg } 5 - \text{Rp } 5)^2 = (\text{Rgg } 7 - \text{RP } 7)^2$$

where,
$\text{Rgg } 5 = 0.851 \text{ Rp } 5 + 0.355 \text{ Rp } 7$
$\text{Rgg } 7 = 0.355 \text{ Rp } 5 + 0.148 \text{ Rp } 7$
$\text{Rp } 5 = \text{Band } 5$
$\text{Rp } 7 = \text{Band } 7$

Perpendicular Vegetation Index 6

$$\text{PVI6} = (\text{Rgg } 5 - \text{Rp } 5)^2 + (\text{Rgg } 6 - \text{Rp } 6)^2$$

where,
$\text{Rgg } 5 = -0.498 + 0.543 \text{ Rp } 5 + 0.498 \text{ Rp } 6$
$\text{Rgg } 6 = 2{,}734 + 0.498 \text{ Rp } 5 + 0.457 \text{ Rp } 6$
$\text{Rp } 5 = \text{Band } 5$
$\text{Rp } 6 = \text{Band } 6$

Difference Vegetation Index

$$\text{DVI} = 2.4 \text{ Band } 7 - \text{Band } 5$$

Regression analyses were performed with each of the Landsat models and individual MSS bands, with ground measured variables including crop cover, shadow cover, plant height and leaf area index. Somewhat surprisingly, Richardson and Wiegand (1977) found that single channel correlations of Band 5 with plant height and crop cover, and Band 6 with leaf area index were higher than those produced by any of the vegetation index models. Deering and Haas (1978), in a similar study on rangeland vegetation at Throckmorton, Texas, compared individual MSS bands, ratios, and vegetative index models (TVI, TVI6, PVI, PVI6, GVI, DVI, and SBI) with herbaceous green biomass, and showed TVI6 to be most highly correlated to green biomass ($R^2 = .90$), and all vegetation index models except SBI to be superior to individual bands for estiating green biomass.

The data presented by Deering and Haas (1978) suggest Landsat MSS data are sensitive to seasonal changes in vegetation growth conditions provided measurements are taken within a uniform vegetation-soil system. McDaniel and Haas (1980) compared Landsat MSS data and vegetation data collected at four dates and from six study sites in a similar vegetation-soil type and showed two vegetation index models, TVI6 and GVI, to be highly correlated with selected natural vegetation parameters. The GVI developed by Kauth and Thomas (1976) was highly correlated with wet green herbage yield; dry green herbage yield; and cured vegetation cover. TVI6, developed by Rouse et al. (1974), was more highly correlated with green vegetation cover and vegetation moisture. The close relationship of TVI6 and GVI to vegetation parameters associated with actively growing vegetation (i.e. green yield, green cover and plant moisture content) indicates that quantitative measurement of vegetation conditions is possible from Landsat MSS data.

CONCLUSION

Landsat multispectral scanner data provides a synoptic view of vegetated landscapes and is an excellent data source from which to inventory and monitor selected vegetation features. Satellites planned to be launched in the future may be more refined and offer a better data source. The classification and description of natural vegetation using the approach outlined in this paper is most appropriate for use and application in a regional vegetation survey program. Broad scale mapping of uniform vegetation-soil systems from space imagery provides the first step for gathering data in an arid land environment. Use of Landsat digital data for the quantitative assessment of vegetation conditions within mapped vegetation-soil systems is the second step to monitoring from Landsat.

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RESUMEN

El mosaico Landsat multiespectral y la data digital son adecuados para clasificar y cuantificar las condiciones naturales de la vegetación en una base regional. El primer paso al utilizar la data Landsat MSS para programas de tasación regional de vegetación es estratificar los sistemas vegetación-suelo relativamente uniformes en el mosaico Landsat. El segundo paso es establecer las relaciones funcionales de los modelos de reflectancia derivados del Landsat con los diferentes parámetros de vegetación que se encuentran en cada sistema vegetación-suelo estratificado que se ha de inventariar.

Landsat Digital Analysis Techniques Required for Wildland Resource Classification[1]

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Abstract.--Landsat data has been available since 1972, and are being used to inventory, map, and monitor changes in natural resources. Application of this data to resource management problems necessitates using interpretive techniques that allow quick, consistent, and accurate extraction of pertinent information. Image analysis techniques for preprocessing and classifying Landsat digital multispectral (MSS) data are required for successful application to natural resource inventories. Merging other digital data sources, such as terrain data with Landsat data, in the classification process, improves the classification accuracy. Landsat classification results are useful for construction of sampling frameworks for resource inventories and for incorporation into resource data bases for assisting in resource management decisions.

INTRODUCTION

Landsat multispectral data, available since 1972, are being used to monitor changes in Earth resources, map resources over extensive regions, and inventory specific resource parameters. Application of these data to resource management problems necessitates development of interpretative methodologies that allow quick, consistent, and accurate extraction of pertinent information. In the 1960's, considerable effort was placed on developing digital and analog multispectral processing capabilities. Methodologies to merge Landsat data with resource data collected from aerial photographs and ground data sampling have been developed in the 1970's. Analysis approaches have also been developed to accommodate new data sources such as digital terrain data. The trend has been toward more interactive systems that provide users greater flexibility in analyzing multispectral data and disparate data sets more efficiently than previously possible. Landsat derived vegetation classes have been used in sampling frameworks for estimating classification accuracy, estimating areas, and estimating timber volume or forage production. Landsat derived vegetation classes have been integrated with resource data bases to provide comprehensive resource information needed for resource management decisions.

The purpose of this paper is to discuss analysis techniques required for successful application of Landsat MSS data to natural resource inventories and to discuss resource sampling and digital data base applications of Landsat derived data.

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IMAGE PROCESSING

Radiometric Corrections

Landsat MSS data are characterized by radiometric anomalies including: bad data lines and points, radiometric striping, and atmospheric scattering effects. Bad data lines, line segments or pixel dropouts are referred to as intermittent striping problems. Two techniques are commonly used to insert new data in place of bad data. One technique is to replace the bad data line with the preceding line. A second technique is to replace the bad data by interpolating between the brightness values from the pixels in the line before and after the bad data line. Although the difference between the two techniques seem slight, the latter tends to provide a more accurate representation of the correct brightness value.

Radiometric striping, caused by unequal response of the detectors in the MSS to incident electromagnetic energy, is characterized by variations in film density that should be uniform but often appear as systematic light or dark lines across an image. Radiometric striping introduces anomalous variations in the spectral signatures of resource cover types and will influence classification performance because of 1) high variances, or 2) lack of training data to characterize signatures of picture elements occurring in lines with striping.

Several techniques are available to minimize effects of striping. One technique, histogram normalization, calculates the mean brightness value for each detector in each band. A normalization factor is calculated by ratioing the maximum mean to the mean of each detector. The normalization factor for each detector is then multiplied by the brightness value of each pixel recorded by the detector and the pixel is assigned a new brightness value. Although this technique minimizes striping, residual striping, caused by localized radiometric anomalies, are sometimes found in the data. Other approaches to minimize striping

effects in Landsat data are described by Rohde, Lo, and Pohl (1978). It should be noted that radiometric calibrations and corrections are applied to Landsat data by the Image Processing Facility (IPF) at the Goddard Space Flight Center (GSFC), Greenbelt, Maryland. These procedures are discussed in U.S. Geological Survey (1979). However, residual striping are often found in Landsat digital data, thus, the user is obliged to perform radiometric corrections, as discussed above, to minimize the effect of these anomalies on the interpretation and analysis of Landsat data.

Geometric Rectification

Landsat digital data have inherent geometric errors that must be corrected if the data are to be correctly displayed on film, map overlays, or registered to some geographic reference system. The geometric errors can be either systematic and predictable or random and measurable (Bernstein and Ferneyhough, 1975). Geometric errors that are systematic and predictable can be modeled and corrections applied to the data (Anuta, 1973; Bernstein and Ferneyhough, 1975). However, errors caused by variations in spacecraft attitude and altitude are not systematic or predictable. In natural resource inventories, accurate location of sample plots or specific resource features are required, thus, the non-systematic errors must also be corrected.

When variable errors are in the data, the effect of the errors can be determined by measuring the apparent displacements of ground control points. Ground control points are features that can be located in an image and whose geographic positions are known. Once the displacement of control points is known, correction functions or mapping transformations are derived and used to calculate coordinates and map pixels into their correct spatial location on the corrected image. The corrected location of a pixel seldom coincides with a pixel in the distorted image, thus the distorted image must be resampled to determine the brightness value of the pixel in the corrected image. Three commonly used resampling techniques are nearest neighbor, bi-linear interpolation, and cubic convolution. In nearest neighbor resampling, a pixel in the corrected image is assigned the brightness value of the nearest pixel in the uncorrected image. In bi-linear interpolation resampling, the brightness value of a pixel in the corrected image is determined by interpolating between brightness values of the four nearest pixels in the uncorrected image. In cubic convolution resampling, the brightness value of a pixel in the corrected image is determined by interpolating between the brightness values of 16 nearest pixels in the uncorrected image. More detailed discussions of geometric correction and resampling techniques are discussed in Anuta, 1973; Bernstein, 1973 and Goetz, and others, 1975.

In addition to geometrically correcting Landsat MSS data or classification results to a geographic reference system, geometric correction functions can be used to register one Landsat scene to another, register any graphic or map data to Landsat data, or compute the location of sample units for resource inventory applications. These capabilities are useful in subsequent analysis tasks to perform image stratification, calculate training statistics, refine image classification, allocate sample units, and estimate the geographic coordinates of sample units.

Prior to February, 1979, Landsat computer compatible tapes were not geometrically corrected and the user was obliged to correct the data. Since February, 1979, Landsat data received by the National Aeronautics and Space Administration (NASA) tracking stations, are converted into digital form on high density tapes (HDTs) by the Image Processing Facility (IPF) at the Goddard Space Flight Center. The HDTs are shipped to the EROS Data Center where they are converted into customer products by the EROS Data Center digital image processing system (EDIPS). While computer compatible tapes of Landsat data, without geometric corrections applied, can be ordered, the user may now also order geometrically corrected Landsat digital data resampled with either nearest neighbor or cubic convolution resampling techniques and registered to either a Space Oblique Mercator (SOM), Universal Transverse Mercator (UTM), or Polar Stereographic (PS) projection (U.S. Geological Survey, 1979; and Holkenbrink, 1978).

DIGITAL IMAGE CLASSIFICATION

Basically, the purpose of digital image classification is to group a large number of pixels into a number of meaningful categories that can be related to resource features. This grouping is normally done by a classification decision rule (e.g., minimum distance to the mean, parallelepiped, maximum likelihood). In resource inventory projects, Landsat digital data are commonly analyzed using interactive analysis procedures and a multispectral classification algorithm. Most classification algorithms require the analyst to specify training statistics for the desired resource classes. Resource assignment is based on the similarity of an unknown pixel's spectral characteristics with spectral characteristics of pixels of a known resource class.

Developing Spectral Training Statistics

Fleming, Berkebile, and Hoffer (1975) describe three approaches used to derive training set statistics for use with a classification algorithm. These can be referred to as supervised, unsupervised, and modified or controlled clustering.

In supervised classification, areas are selected that represent each resource category

and that are spectrally homogenous. Because of variations in spectral characteristics of resource cover types, there often is more than one training area selected for each category. Training statistics, including the mean brightness value within the training area, variance about the mean, and the covariance between data channels are calculated for each training area. Adaptations of this approach use a clustering technique to identify a unique number of spectral classes within each training area. In either case, a resource cover type is normally assigned to each training area prior to deriving the training statistics.

When classifying wildland vegetation, it is often difficult to identify spectrally homogenous training areas for each resource category. Unsupervised development of training statistics uses a clustering algorithm to group pixels selected for training into a number of relatively homogenous spectral clusters. For each spectral cluster, a mean brightness value and its variance for each spectral band and a covariance matrix is calculated. These statistics are used in a maximum likelihood algorithm to classify each picture element into one of the cluster classes. Aerial photographs and field data are used to assign each cluster class to one of the resource cover classes. Clustering of all pixels in a project area into a small number of spectral clusters or classes is sometimes referred to as unsupervised classification.

Typically, five to ten percent of an area may be randomly selected in small blocks to be processed with a clustering algorithm. Using this approach to derive training statistics, it is assumed that the sample data represent all of the cover types in the area. Further, it is assumed that each cover type will be represented by at least one spectral cluster and that each spectral cluster would represent only one cover type. After unsupervised classification, it is necessary to identify the resource category represented by each cluster.

Controlled clustering is another approach to developing training statistics. Using this approach, rectangular shaped training areas, termed cluster blocks, that include several resource cover types are either randomly or purposely selected. Pixels within the cluster blocks are clustered into a number of spectral clusters as in the unsupervised approach. Cluster blocks may be individually or collectively clustered. A line printer map or color display is generated to show the spatial distribution of spectral clusters within each cluster block. Using aerial photographs, ground data, and other supporting data, the resource cover type associated with each cluster is identified.

Some spectral clusters for a given resource cover type may be similar, especially when cluster blocks are clustered individually. A statistical measure of separability, termed divergence, can be used to evaluate which cluster pairs are different and which cluster pairs are similar. Similar clusters, those pairs having a small divergence, can be combined when associated with the same resource cover type. The resulting combined training statistics set is used in the maximum likelihood classification algorithm to assign all pixels to known resource cover types.

Fleming and Hoffer (1977) evaluated several training approaches, including those discussed above, to better understand the capabilities and limitations of each. They reported that controlled clustering of individual cluster blocks was the best approach. This approach required the least amount of support data, required relatively few man-hours of time, reduced computer time, and resulted in the highest overall classification accuracy. Fleming and Hoffer (1977) suggested selecting approximately 40 x 40 pixel cluster blocks containing three to five spectrally similar cover types. Individually clustering each block into 12 to 16 clusters, and subsequent grouping of similar clusters from different blocks, resulted in the best classification accuracy for forested test areas in Colorado.

Rohde (1978b) discusses the importance of stratification of Landsat data, prior to or after image classification, to improve classification results. In a study using Landsat data to inventory and map flooded agricultural land in North Dakota, three strata were defined to minimize variation in land cover classes within each stratum. Separate training statistics were developed for each stratum. Each stratum was classified separately and after classification, the three strata were combined to reconstruct the original image. Classification accuracy was improved 5 to 10 percent over accuracy from an unstratified approach. In an Alaskan resource classification study, classification confusion between water and barren land on steep north facing slopes was eliminated through stratification after classification. Mountainous areas where the misclassification was evident were delineated, after which all barren areas, originally classes as water, were redefined into the barren cover class.

Ancillary Resource Data in Digital Image Classification

In some remote sensing classification studies, information requirements exceeded the level of information that could be reliably produced from digital image classification of Landsat data. Early remote sensing studies to classify vegetation reported accuracies which resource managers generally described as unacceptable. Use of ancillary resource data has improved classification methods and accuracies. Also, the use of ancillary data often results in more detailed classification than what could previously be obtained, and provides objective descriptions of the resource composition of

Landsat derived computer classes.

In a wildland resource inventory of northwestern Arizona, 76 computer classes were aggregated into nine strata and sampled using a stratified cluster sample (Rohde, and others, 1979). Sample units and flight lines were plotted on 1:24,000-scale topographic maps and used to acquire 1:6,000-scale natural color aerial photographs in stereo over each sample unit. The perimeter of each sample unit was transferred onto 1:24,000-scale orthophoto quadrangles; the four corner points of each sample unit were transferred to corresponding 1:6,000-scale natural color transparencies, and each sample unit was partitioned into 64 photo plots, each corresponding to approximately one Landsat pixel (0.4 ha). Each photo plot was interpreted according to a resource cover type classification developed for the project. A description indicating the proportion of resource cover types associated with each computer class was developed by comparing the photo interpreted data with the corresponding computer classified data (table 1). This description can also be developed for aggregations of computer classes.

Table 1.--Percentages of cover types based on aerial photo interpretation of 60 photo plots in computer class 23.

Coniferous Forest		Evergreen Woodland		Mountain Shrub	
Ponderosa Pine - Sagebrush	2	Juniper/ Pinyon	1	Mixed Chapparel	2
		Juniper/ Pinyon-Shrub	95		
	2		96		2

In a forest stand classification effort in western Washington, ancillary data were used to describe and aggregate spectral clusters (Johnson and others, 1979). Landsat data were geometrically corrected and registered to a 220-foot State Plane coordinate grid. The State of Washington's Gridded Resource Inventory Data System (GRIDS) is aligned to State Plane coordinates and individual GRIDS one-acre sample plots are located at 660-foot intervals. Thus, after geometric registration, every third Landsat pixel in every third line was aligned to the location of a GRIDS plot. Landsat pixels aligned to the GRIDS plots were grouped into 53 spectral clusters. A series of tables, similar to table 1, were produced using GRIDS ancillary data to show the resource composition of each spectral cluster. The resource characteristics included cover type group, basal area per acre, number of stems per acre, average stem diameter, and stand age. Graphs which summarized all resource characteristics for each spectral cluster were also generated (figure 1).

Tabular comparisons of ancillary resource data and spectral clusters provide objective evaluations of resource composition of Landsat derived spectral classes. Use of ancillary resource data can direct the grouping of spectral clusters into meaningful resource classes or identify the need to recluster spectral data into more separable clusters. Also, objective resource descriptions of spectral clusters can be used to identify when resource cover types are not spectrally separable, thus, necessitating the use of topographic data to improve separability between vegetation types.

Terrain Data in Digital Image Classification

Spectral response of individual resource cover classes in Landsat data is often highly variable due to topography. A vegetation cover type will have a different spectral response on mountainous slopes than on flat terrain. Two vegetation cover types, spectrally separable on flat terrain, may have similar spectral responses when occurring in mountainous or hilly areas. Thus, homogenous spectral classes will often have diverse vegetation cover type compositions. The capability to reliably classify cover types in hilly and mountainous areas is often reduced since topography has a significant effect on spectral response.

Topography has a significant effect on micro-climate and environment of an area. The occurrence and distribution of vegetation cover types is greatly influenced by environment and topography. Even when different vegetation cover types are spectrally similar, they may occur in different topographic conditions, and thus be separable with the use of terrain data. Quantification of the topographic distribution of vegetation cover types provides an additional approach to improve classification results.

Digital elevation data, produced by the Defense Mapping Agency (DMA), is available through the National Cartographic Information Center (NCIC). These data are produced by digitizing 1:250,000-scale topographic maps and are composed of elevations estimated to the nearest foot for approximately 200-foot square cells. Data is provided in one degree blocks and is registered to a UTM grid. The U.S. Geological Survey has also produced Digital Elevation Model (DEM) data for 7½ minute quadrangles. Elevations are provided to the nearest meter on a user specified UTM grid. The DEM data, available for limited areas, is more accurate than the DMA elevation data.

Digital elevations are provided in, or can be reformatted to, a line-raster matrix of values. Terrain slope and aspect can be determined by comparing the elevation of a cell to elevations of surrounding cells. Software to perform this calculation is available

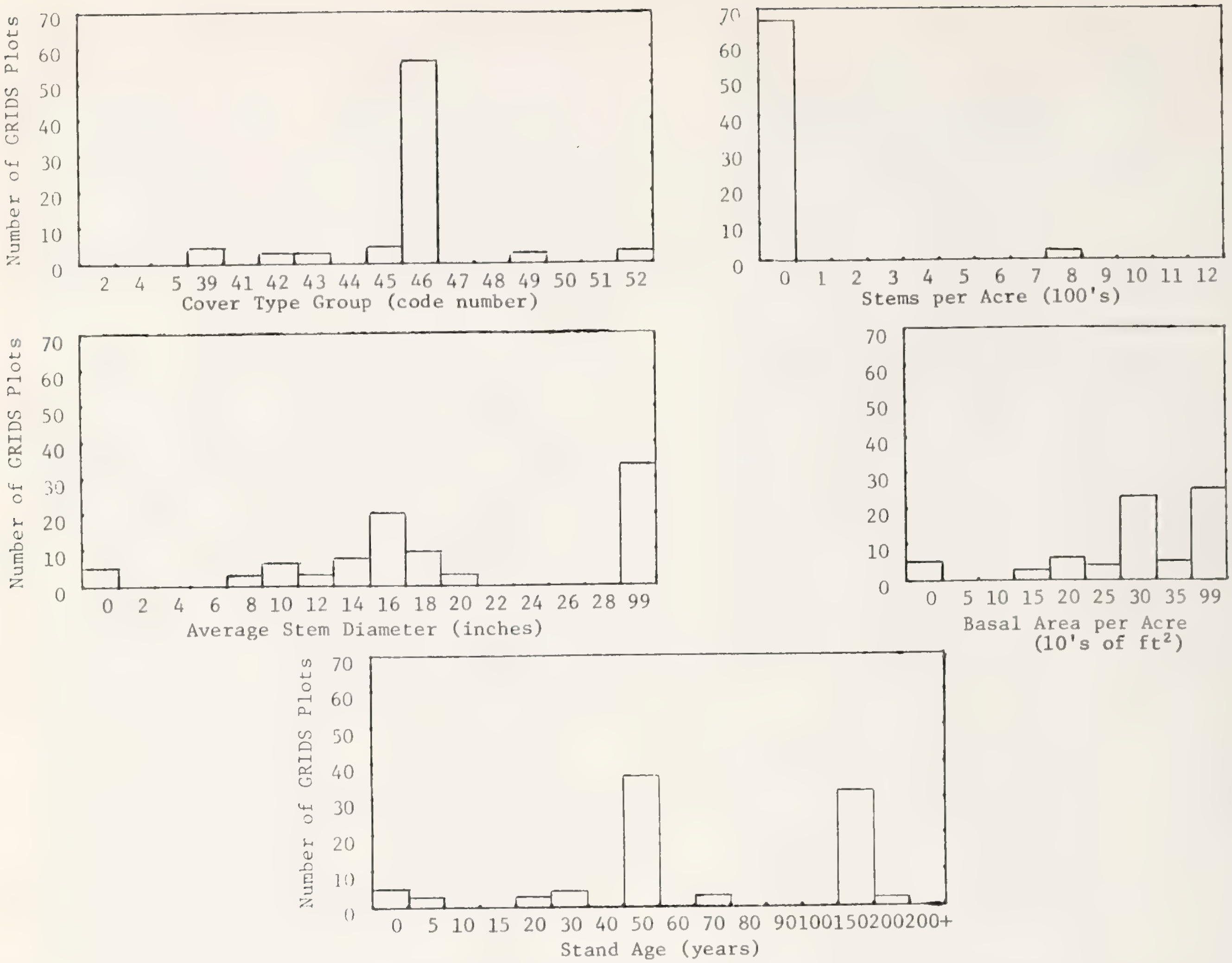

Figure 1.--Distribution of resource characteristics for spectral cluster number 44. Resource content of all 53 spectral clusters was analyzed using graphs made from GRIDS data. Cluster 44 is a sawtimber class comprised of 50-year-old second-growth and old-growth conifer.

in many digital image analysis software packages. Landsat spectral data and digital elevation, slope, and aspect data must be geometrically corrected and aligned prior to classification.

Several approaches have been used in applying terrain data to digital image classification. Simple radiometric corrections have been made to original Landsat data by normalizing the relative brightness values by the incident solar radiation to specifically remove terrain effects (Tom and Miller, 1979). Incident solar radiation at the time of Landsat overpass can be determined from terrain slope and aspect and the position of the Sun. Normalization simply involves the division of digital brightness values in individual bands by the computed incident radiation on a pixel-to-pixel basis. If illumination effects are proportionally constant for both the spectral band and the computed incident radiation value, the ratio of the two parameters will negate the effect topography has on spectral response. Once this simple correction has been applied to spectral values, clustering and classification of the corrected image data can proceed. Tom and Miller (1979) used this approach in a linear discriminant analysis for mapping forest site index.

Several investigations have used terrain variables as a means to divide areas into strata to minimize the variation of vegetation cover types within each stratum. In a forest-species classification effort in northern California, Strahler, Logan, and Bryant (1978) studied several approaches using terrain data. In one approach, the study area was divided into three elevation strata (high, middle, and low) and three aspect strata (northeast, southwest and neutral). Probabilities of each vegetation cover type occurring in each topographic strata was estimated from data collected in a ground sampling program. Probabilities of vegetation cover type occurrence were used as prior probabilities in a classification algorithm to modify

the probabilities obtained from spectral data alone. In another approach, they used topographic variables as additional channels in the conventional multivariate classification approach. The report noted from 13 to 27 percent improvement in classification accuracies over using Landsat data alone.

In the wildland resource inventory in northwestern Arizona, topographic data was used to reclassify results derived from only Landsat spectral data. Vegetation/terrain relationships were evaluated by examining a series of contingency tables that compared photo-interpreted vegetation data to elevation, slope, and aspect. There appeared to be little relationship between the occurrence of vegetation types and slope or aspect. However, there were definite relationships between elevation and vegetation types. For example, creosote bush occurred between the elevation range from 1,400 feet to 4,800 feet and sagebrush occurred between 4,200 feet and 5,800 feet. Other contingency tables were developed that compared photo-interpreted vegetation data and elevation data to Landsat spectral classes on a pixel-by-pixel basis for selected sample areas. Using a number of contingency tables and the expertise of field resource personnel, elevation decision rules were established for each of 76 computer classes. The elevation decision rules were tested and applied within each computer class. Reclassification results were combined to derive a final classification product composed of eight arid-land cover classes.

Fleming and Hoffer (1979) used DMA digital terrain data and digital Landsat data in a two-layered classification approach to classify forest species in Colorado. A topographic distribution model was developed for coniferous, deciduous, and herbaceous forest land cover types. Within each major vegetation type, the cover-type topographic distribution models were used in a stepwise linear discriminant analysis function to evaluate the potential for distinguishing among cover types. Elevation and aspect were determined to be significant variables in distinguishing among cover types. Landsat spectral training set statistics were developed by individually clustering 40 x 40 pixel blocks. The first layer of the two-layered classifier used spectral training statistics to classify Landsat data into the major vegetation types: coniferous, deciduous, herbaceous, barren and water. Major vegetation types were subdivided into individual forest cover types in the second layer using topographic distribution models. For example, the deciduous type was subdivided into alpine/willow, aspen, and oak cover types, and the coniferous type was subdivided into five cover types composed of spruce, alpine fir, douglas-fir, white fir, and ponderosa pine.

Classification accuracies were compared for several combinations of spectral and terrain data and for two classification approaches to determine the value of topographic data and the two-layered classification approach. Utilization of topographic data improved classification accuracy from 49 percent using spectral data alone to 66 percent when using both spectral and topographic data. There was no significant difference in overall classification accuracy between the two-layered approach and a single-layered approach using seven channels of spectral and topographic data. However, Fleming and Hoffer (1979) reported that the layered approach was better because it raised the individual accuracies of the worst classes, provided a logical sequence of decision points, and significantly reduced computer time.

Shasby (1980) and the senior author used Landsat data and DEM topographic data in a two-layered maximum likelihood classification of forest fire fuels in northwestern Montana. The first level of the layered classifier involved classification of Landsat spectral data into 48 spectral clusters. Spectral clusters representing more than one fuel type were identified by generating tables, similar to table 1, which described the fuel type composition of each spectral cluster. Within those spectral clusters representing more than one fuel type, terrain and fuel type relationships were examined. Four terrain variables (elevation, slope, [TANGENT (slope) x COSINE (aspect)], and [TANGENT (slope) x SINE (aspect)]) were identified for predicting the occurrence of fuel types. Statistics of these variables were calculated for each fuel type, in each cluster, and used in the second layer of the classifier to discriminate between fuel types within spectral clusters. Classification results from separate clusters were combined to form a single fuel-type classification map.

Summarizing Classification Results

Image and terrain classification results show the areal extent of resource and vegetation cover types. Because the data are in digital format, the area within each cover class can be easily tabulated. In most inventorying projects, statistical summaries are desired by ownership, administrative units within an ownership, or political boundaries. If these boundaries are plotted onto maps and digitized, the boundaries can be registered to Landsat data. The area of each cover type can then be summarized within each defined boundary. This technique has been used in many forest, range and arid-land resource inventories.

SAMPLING FOR CLASSIFICATION ACCURACY ASSESSMENT AND RESOURCE INVENTORY

Although areas of cover classes can be tabulated for any polygonal area within the Landsat data, there is no indication of classification accuracy nor can a confidence statement be placed on the tabulated figures. In

resource inventories, the parameter of interest may not be measured precisely on Landsat imagery; thus, sampling procedures are needed to derive estimates of the parameter of interest and to evaluate classification accuracy.

Verification of Classification Accuracy

Classification errors can occur either as errors of commission or errors of omission. A commission error occurs when a Landsat pixel classified as a specific cover type is, in fact, a different cover type. An omission error occurs when a specific ground plot, known to be a certain cover type is, in fact, classified by Landsat as a different cover type. Evaluation of classification errors necessitates sampling each of the cover classes. To determine the accuracy of the Landsat classification results, an independent set of sample plots should be acquired to eliminate bias resulting from working with data used previously in the classification process. One approach that could be used is a simple random sample of individual picture elements within each computer class or cover type. Another technique that can be used is a simple random cluster sample with unequal size clusters. Cluster sampling reduces per plot sampling cost since once a plot is found, it is less expensive to locate adjacent plots that comprise the cluster then it would be to locate widely scattered plots. Careful consideration of cluster size and number of clusters sampled is necessary. A discussion of cluster size and determination of sample size can be found in Cochran, 1977; Sukhatme and Sukhatme, 1970.

Analysis techniques are used to superimpose a sample unit grid onto the classification results, randomly select sample units, and tally the results within the selected sample units. After visiting each of the selected clusters on the ground, the classification results can be compared to the ground data. Sampling statistics are used to estimate the proportion of Landsat pixels correctly classified and the standard error associated with this estimate (Scheaffer, Mendenhall, and Ott, 1979).

Sampling Procedures for Area Estimates

Landsat derived classification results are in digital format and the area of each cover type can be easily tabulated. However, a confidence statement cannot be placed on the tabulated figures. One sampling method that can be used to estimate the area within each wildland vegetation cover type and to calculate a confidence interval for each estimate is a stratified-cluster sample. This method utilizes the Landsat digital classification results to stratify the project area and photo interpretation data or ground data to estimate the area of each cover type within each sample cluster. The purpose of stratifying is to partition the project area into strata that are relatively homogenous with respect to the predominant wildland vegetation found in the strata. This approach was used to estimate the area for each of eight broad vegetation types in northern Arizona. Sampling errors of less than 10 percent were achieved for several cover types whose combined area comprised approximately 95 percent of the total area (Rohde and others, 1979).

Investigators have shown that when remote sensing imagery at several scales is available, it is often most efficient to first make a large number of fast, inexpensive measurements of a parameter (X_i), on small scale, low resolution imagery, and then correlate this parameter with the parameter of interest (Y_i), (Gialdini and others, 1975). A second phase involves selecting a small number of sample units on which the parameter of interest (Y_i) is measured precisely on larger scale, higher resolution images. Statistical methods are then used to estimate the parameter of interest from the measurement made on each image type and to estimate the variability about the estimated total.

Two phase sampling is a common sampling method that can be used with Landsat data. In two-phase sampling, sample units are the same size in each phase. The Landsat classification results provide the quick estimates in the first phase. A subsample of the first-phase sample units are selected for more precise measurements in the second phase. A least squares regression of estimates from the second phase on estimates from the first phase are used to adjust estimates made from the first phase (Rohde, Taranik, and Nelson, 1976).

The ability to overlay a sample unit grid of varying size on Landsat data, tabulate classification results within sample units, and calculate geographic coordinates of sample units, provide data that resource specialists can use to define sampling schemes or allocate sampling efforts to derive resource estimates. Landsat data, multi-phase and multi-stage sampling techniques have been used in numerous resource inventory projects (Rohde, 1978a).

LANDSAT-DERIVED CLASSIFICATION RESULTS FOR DEVELOPMENT OF RESOURCE DATA BASES

Landsat data, and classification maps resulting from digital image classification of Landsat spectral data have been promoted as an important source of information for land resource managers. Landsat data and Landsat classification maps are important data sources because of the spatial nature of the data, availability of the data for large geographical areas, availability in digital formats for data manipulations, cost effectiveness, timeliness, and potential for repeated monitoring of land resources. However, Landsat data and digital classification maps do not provide comprehensive information about land resources

required to make decisions. When Landsat digital classification results are incorporated with other information, in a comprehensive data base, the collective information can provide resource managers assistance in making land management decisions.

Resource Data Base Concept

The resource data base concept integrates spatial and tabular data from a wide variety of sources to provide a comprehensive collection of digital resource data. When manipulated, the collective data can provide information required to make resource decisions. A comprehensive data base and manipulation system will be capable of combining and cross-referencing diverse data elements such as conventional maps, Landsat classification maps, terrain information, and tabular data. Such a collection of data in a manipulation system provides a resource manager with the ability to visualize the integration of data elements which otherwise would have to be examined and analyzed independently in a manual fashion (Smith and Blackwell, 1980).

Data base and manipulation systems are commonly referred to as Geo-based Information Systems and many are available (Knapp and Rider, 1979). A typical system has the ability to integrate data digitized from conventional maps including administrative, political, or geographical boundaries; linear features such as roads and streams; and point features, such as point sources of water and archeological sites. Unconventional map data including Landsat derived resource classification results and digital terrain data, and tabular data collected from ground sampling or from interpretation of aerial photographs can typically be incorporated into such a system. Each spatial data type is geometrically corrected and registered to a common planimetric base, thus creating a system of data planes. Data planes, when superimposed, provide a collection of data concerning a given parcel of land. Tabular data can be referenced to particular polygons or classes within the spatial data planes. Thus, the resource manager can specify the manipulation of data from a variety of sources, which despite their original geometric disparity, are referenced to a common geographical base (Smith and Blackwell, 1980).

Integration of data planes in manipulative and analytical procedures can provide the resource manager information required for land management decisions. Surface analysis procedures involve relationships in a single data plan. Examples of surface analysis include determining distances from road or water sources and determining areas visible from defined ground locations. Overlay analysis provides for interaction of two or more data planes. Identification of areas, meeting multiple vegetation and terrain criteria, that describe wildlife habitats is one example of overlay analysis.

Resource Data Base Applications

In the northwestern Arizona resource inventory study, a digital resource data base composed of vegetation data, and elevation, slope, and aspect data for one million hectares was constructed. The vegetation data plane was derived from digital classification of Landsat and terrain data. Photo-interpreted community level vegetation data was also incorporated into the data base and used to describe community compositions of Landsat vegetation cover classes. Landsat derived vegetation and terrain data planes were combined to produce terrain summaries of each vegetation cover class (Miller and others, 1980). The elevation range of each vegetation cover class was provided, as well as acreage and percent summaries by five slope classes and eight aspect classes.

In another application of the Landsat derived vegetation and terrain data base, potential areas for selected resource management activities and potential wildlife habitats were mapped. Management activity areas included potential pinyon/juniper chaining areas, sagebrush treatment areas, and grazing suitability areas by slope class. Potential wildlife habitats included mule deer winter range, mule deer summer range, desert bighorn sheep habitat, and antelope habitat. Subsequent use of the resource data base has included identifying potential management activity areas and potential wildlife areas for an administrative planning unit within the entire project area. In these applications of the resource data base, resource managers defined vegetation and terrain criteria for each activity or habitat. For example, potential bighorn sheep habitat criteria were Mohave desert shrub, Great Basin desert shrub, and mountain shrub areas between 3,000 and 8,200 feet and on greater than 20% slopes. Areas meeting all criteria were identified by a simple digital overlay analysis procedure and printed on 1:250,000-scale transparent map overlays.

Johnson and Loveland (1979) reported the application of digital image classification techniques to development of a resource data base for determining land suitabilities for conversion of rangelands to irrigated croplands in the Columbia River Basin. The feasibility analysis was designed to evaluate existing land cover, soil characteristics and slope as data planes in creating a composite map of suitability for irrigation development. A 1972 Landsat subscene was digitally classified into the following land cover classes: irrigated land, dryland agriculture, rangeland, and wetland. Soils maps of the area were interpreted to determine the potential of soils to support irrigation development. The resultant potential irrigation map was digitized and entered into a resource data base along with slope derived from digital terrain data. A map of potential irrigation development was derived based on 1972 land cover, soils, and slope.

In a study to develop a resource data base for forest fire management planning, Shasby (1980) and this senior author used image processing techniques with digital Landsat data and digital terrain data. Six forest fire fuel types were mapped for a 100,000 hectare site in northwestern Montana. The six fuel types were taken from a set of twenty fuel models developed for the 1978 National Fire Danger Rating System. The fuel models are designed to work directly with mathematical fire models to analyze wildfire potential at various levels of planning. The resulting resource data base is composed of forest fuel types, and elevation, slope, and aspect data. To enhance the interpretability of the final product and add another valuable piece of information to the fire planning process, the road network was digitized, registered, and merged into the resource data base.

By entering this resource data base into a mathematical fire behavior model to simulate wildland fires and varying other input variables, such as meteorlogical data, a scenario of fire behavior patterns and planning regimes can be generated and evaluated. Such a system will enable fire planning at resolution levels from 10 acres to several thousand acres through aggregation of fuel and topographic data. The forest fire fuels data base will permit considerable flexibility in fire planning efforts. Another application of the data base is the link with a system to detect and locate lightning strikes to predict the probability that a fire will result. Knowledge of the fuel type at the strike location is important for this prediction.

A LOOK FORWARD

Efforts to improve the application of Landsat digital analysis techniques for natural resource inventories will continue. First, new satellite sensors in the 1980's will provide greater spatial and spectral resolution. Changes in preprocessing techniques will lead to improvements in the radiometric and geometric qualities of satellite data. Landsat derived classification results will have increased accuracy with better quality satellite data. Secondly, availability of new data such as high quality digital terrain data, and availability of more sophisticated analysis approaches to incorporate new data sources will improve classification results. Also, better understanding of fundamental environmental and spectral relationships will lead to improved analysis procedures to incorporate those concepts in large area land cover and vegetation classification efforts. Finally, efforts will be directed towards developing comprehensive land and resource information data bases. Landsat data processing will be designed around producing results which can be related to other resource information and inventory data to provide comprehensive information for resource management decisions.

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RESUMEN

Los datos Landsat han estado disponibles a los investigadores y científicos de recursos desde el 1972, y están siendo utilizados para inventario, para cartografía, y para observar cambios en los recursos naturales. La aplicación de esta data a problemas de manejo de recursos necesita del uso de técnicas interpretativas que permitan la obtención rápida, consistente y precisa de la información pertinente. Se requieren técnicas de análisis de imágenes para preprocesar y clasificar data multiespectral y digital Landsat para su aplicación exitosa a los inventarios de recursos naturales. La combinación de otras fuentes de datos digitales, tales como datos de suelo combinados con la data Landsat, en el proceso de clasificación, mejora la precisión de la clasificación. Los resultados de la clasificación Landsat son útiles en la preparación del marco de muestreo para los inventarios de recursos, y se pueden incorporar a la data básica de recursos para ser utilizados al hacer decisiones sobre el manejo de recursos.

A Digitized Classification for Liquid Surface Water Resources in Arid Natural Areas[1]

Bryan T. Brown[2], Peter S. Bennett[2], R. Roy Johnson[3] and M. Susan Moran[4]

Abstract.--A digitized, hierarchical classification for interior surface water resources in Southwest natural areas is presented. The classification addresses physical parameters through time and space, biological concerns, chemical and water quality attributes and major uses. Describing in sequence a prescribed set of resource variables, the classification emphasizes the needs of the natural area manager. The system is designed to facilitate computer storage of data.

INTRODUCTION

A logical first step in the management of Southwest natural areas would be the systematic inventory of local natural resources. Since available water is a major limiting resource in the Southwest, a comprehensive inventory of surface water resources is of primary importance. A useable classification system for these surface water resources then becomes necessary to allow for easy computer storage of data. A compatible classification system acting as the interface between data and availability of results to user groups is an effective means of technology transfer as defined by Viessman and Stork (1973) and further discussed by Doyel (1974). The usefulness of water resources data to the natural area manager is determined to a great extent by the method used to present the data. In this case, an appropriate classification system becomes an important tool for management. Naturally occurring water resources are the primary consideraation of this classification, although it does address various man-altered or artificial types. Even the largest and most pristine Southwest natural areas, such as Grand Canyon National Park in Arizona for which this classification was originally designed, exhibit a variety of water resource modifications.

This paper outlines such a regional resource classification applicable to interior surface waters of the 'natural' Southwest region of North America as defined by Brown et al. (1979). The classification presents a broad spectrum of resource variables useful to the natural area manager on a local or regional level. It is intended to relate both water resources data and other information applicable to a basic resource inventory of the specific natural area. The classification is designed to be computer-compatible.

The digital format is after the ecosystem classification of Brown and Lowe (1974) and Brown et al. (1979, 1980) which is a natural hierarchy with an evolutionary derivation. The surface water classification presented here is a non-natural, artificial hierarchy as it is intended as a classification for management and not as a natural grouping of surface water types.

The classification of surface waters was first outlined by Meinzer (1923) in an attempt to categorize the natural occurrence of both marine and flowing, impounded, and frozen interior freshwater. A stream classification based on stream order numbers was put forth by Horton (1945) and further discussed by Strahler (1957). The classification of stream networks was explored by Shreve (1966, 1967). Wetlands and deep-water habitats of the United States were classified in a hierarchical structure attempting to define a natural complex of surface water types in both marine and freshwater situations (Cowardin et al. 1977, 1979). However, that classification is a non-digitized system designed to encompass the entire United States. Brown et al. (1978) classified perennial streams and some important wetlands in Arizona on the basis of volume or size, and flow regulation. This was an important step in

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recognizing the classification priorities for water resources in the Southwest. No other classification of surface water resources presently exists for use in arid lands natural areas in the Southwest at the level of detail needed to aid in the systematic and intensive management of these areas.

THE CLASSIFICATION SYSTEM

Using the System

To derive the classification and the code, numerals at each hierarchical level are combined in sequence to yield an 11-digit number (table 1). Numerals to the left of the decimal refer to physical parameters of the surface water resource, while numerals to the right of the decimal represent biological, chemical and water quality attributes, and major uses. A zero should be inserted at any level where appropriate information is lacking. The terms acre-foot (ac/ft), cubic feet per second (cfs), and gallons per minute (gpm) are used throughout.

The system should be modified to meet specific goals for local user-needs. It is recommended, however, that levels to the left of the decimal remain unchanged for the continuity of physical appearances throughout the Southwest. In this way, basic data on the nature of the site could be more readily compared to data gathered from other areas. However, levels to the right of the decimal, the levels which are the most subjective in terms of perceived importance, could be changed. For example, the classification could be useful in a specific study on the effects of local surface water resources on desert bighorn sheep (Ovis canadensis). Bighorn sheep are sensitive to the availability of water sources in arid lands. Arid lands natural areas are becoming increasingly important to the species' continued survival. To be more useful in such a study, the classification could be modified to the right of the decimal to include a level indicating the relative importance of a water resource site to the sheep. Levels to the right of the decimal which are not needed or are not of primary importance could be dropped or a zero could be inserted at that level if information is lacking. If user values other than the generalized values outlined at the seventh and eigth levels (Appendix I) are of primary importance, those uses should be inserted at the expense of less important values.

First Level

The first digit (e.g. 10,000) refers to the known permanence of the water source through time and thus identifies the reliability of the site with the primary emphasis on perennial sources. Meinzer (1923) placed information of this sort at the lowest level of his generalized surface water classification outline. However, a regional classification for arid lands necessitates placement of this information at the first level. The following definitions are after Meinzer (1923), Langbein and Iseri (1960), the American Geological Institute (1962) and Brown et al. (1978).

Perennial.--A water source which has not gone dry within historic times and which flows continuously throughout the year.

Intermittent.--Source containing water only at certain times during the year when it receives water from springs or runoff. The term may be arbitrarily restricted to sources containing water for periods of at least one month per year, although intermittent sources may go dry only a few months a decade.

Ephemeral.--Sources which contain water only in direct response to precipitation and may be arbitrarily restricted to sources containing water for periods of less than one month per year.

Second Level

The second digit (e.g. 11,000) refers to the continuity of the water source in space and the

Table 1.--A digitized hierarchy for the classification of surface water resources in Southwest natural areas.

Where:

- Level 1) 10,000 = permanence
  - Level 2) 11,000 = continuity in space
    - Level 3) 11,100 = naturalness
      - Level 4) 11,110 = volume and nature of source
        - Level 5) 11,111 = nearest perennial source
          - Level 6) 11,111.1 = legally threatened and endangered biota
            - Level 7) 11,111.11 = primary value or use
              - Level 8) 11,111.111 = secondary value or use
                - Level 9) 11,111.1111 = water quality
                  - Level 10) 11,111.11111 = source of water quality problem
                    - Level 11) 11,111.111111 = nature of water quality problem

nature of its origins. This level addresses flowing water types. Many flowing water types in the Southwest are interrrupted in character, as having their flow disappear underground to possibly reappear later. Most interrupted water sources, meaning either streams or springs, may flow continuously during wet seasons, but are interrupted in character throughout most of the year. Combining information on the continuity of the site through space with single/multiple source qualifiers further characterizes it. Single source types must necessarily be springs and seeps, wells, or streams immediately adjacent to one of those sources. Likewise, a multiple source type must be a stream. An interrupted water supply/single source is a spring, seep, well, or stream immediately adjacent to one of the previous single sources which flows out and disappears underground.

Continuous.--Flowing water type which does not have interruptions in space. It does not have wet and dry stretches.

Interrupted.--Flowing water type which is interrupted in space, containing a) perennial stretches with intervening intermittent or ephemeral stretches, or b) intermittent stretches with intervening ephemeral stretches.

Multiple source.--These are streams. A spring may arise on the surface at one point (a single source) to constitute the entire flow of a surface stream, but even as a tiny ephemeral stream connects to that flow it becomes a multiple source.

Single source.--This includes springs, seeps (usually flow less than 5 gpm-Huntoon 1977), and wells in addition to streams immediately adjacent to a point, or single, source. This includes all flowing water types which arise from a distinct point or locality, even though a spring may arise from the substrate at several points in a 50 meter or more radius.

Third Level

The third level (e.g. 11,100) identifies the naturalness of the site, whether it be a natural water source (e.g. 11,100) or a man-altered/artificial water source (e.g. 11,200). This level serves as qualifier for the different entry choices at the fourth level.

Fourth Level

Information at this level (e.g. 11,110) refers to the nature and/or volume of the water resource. Separate entries are available for both the natural and man-altered/artificial categories. The designation of flowing water as a term with volume categories is used in the place of spring, seep, stream, or river, creek, etc., as the former terms may be misleading, due to local differences in meaning. Seeps intergrade with springs; streams and rivers may be confused; and often a single large spring will constitute the entire flow of a stream in which case the spring is merely the interface between an underground and a surface stream. Information provided at the other levels would help to identify the site more exactly. For example, a continuous, single source, flowing water type is a spring which constitutes the entire flow of a stream throughout most of the year.

Cistern.--This is a large receptacle for storing rainwater, usually for human use. This includes its intake (catchment) area.

Developed spring.--A spring that has been dug, piped, pumped, and/or completely contained in order to obtain maximum discharge for human use of some sort, including livestock watering. This does not include springs of which a portion has been diverted; a developed spring is one in which the entire discharge is being utilized and none of the flow is allowed to escape for natural processes.

Playa lake.--A shallow, wind-scoured basin which may cover a large area. Characteristic of deserts, these basins become the seats of broad, shallow sheets of water which quickly gather and almost as quickly evaporate, leaving mud flats to mark their sites. They are essentially ephemeral freshwater lakes.

Pothole.--This indicates small basins worn into the solid rock by wind, solution, or by sand, gravel, and water at waterfalls and strong rapids. This includes "plunge pool."

Reservoir.--This is a large artificial impoundment on a stream or flowing water type normally associated with stated needs such as domestic water supply, hydroelectric power, recreation or flood control.

Stocktank.--A local term in the Southwest, this is a small artificial impoundment, usually on ephemeral flowing water types, used to hold livestock water.

Storage tank.--Water may be artificially impounded in service tanks or underground reservoirs for future use.

Well.--An artificial excavation that derives some water from the interstices on the rocks or soil which it penetrates. It is applied to the many types of excavations from which water can be drawn by means of siphons, or to artesian wells.

Fifth Level

This level (e.g. 11,111) indicates the distance from the site to the nearest perennial source of water. This level, the last of the physical appearances categories, becomes

important in arid lands when precipitation is seasonally variable or when drought is possible.

Sixth Level

This level (e.g. 11,111.1) refers to legally threatened and endangered animals and plants which are known to occur at the site. Endangered biota should receive special consideration by the natural area manager, and information at this level, if known, can identify those sites which harbor sensitive species. Other entries could be substituted at this level to indicate the presence of locally rare or sensitive species if it is deemed necessary.

Endangered.--A species which is in danger of extinction throughout all or a significant portion of its range (U. S. Fish and Wildlife Service 1978).

Threatened.--A species which is likely to become endangered in the foreseeable future throughout all or a significant portion of its range (U. S. Fish and Wildlife Service 1978).

Seventh and Eighth Levels

These levels taken together (e.g. 11,111.111) refer to the primary and secondary values identified for the site. Entries primarily pertaining to biological or scientific value are represented as well as cultural, recreational, domestic, and agricultural values.

Ninth, Tenth and Eleventh Levels

The last three digits (e.g. 11,111.111111) describe, in turn, water quality variables. The quality of a water source is often the last known variable, hence the placement of information of this sort at the last three levels. The ninth level deals with the presence or absence of a water quality problem at both the public health and non-public health level. The tenth level identifies the source of the existing problem. The eleventh level gives details as to the nature of the problem.

THE CLASSIFICATION SYSTEM AS A COMPONENT OF A SURFACE WATER RESOURCES INVENTORY

This classification was designed to be integrated as part of a comprehensive local surface water resource inventory, such as the inventory of Grand Canyon National Park, Arizona (Brown et al. in press). In the inventory, individual water resources located through field work or literature searches would be identified with a unique site number and located on topographic maps. Standardized field data cards are completed for each site and are indexed by site number. Several field data site cards could be completed for a stream, for example, including its source, its middle reaches, and its lower reaches throughout the year. This would provide necessary information on the water resource through time and space. With the data available for each site, the site can be classified. The classification and raw data for each site can then be analyzed and stored by computer before the presentation of the final results to management.

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APPENDIX I

Classification System for Liquid Surface Water Resources in Arid Lands Natural Areas of the Southwest Region of North America

10000 Perennial Water Source
20000 Intermittent Water Source
30000 Ephemeral Water Source
 1000 Continuous Water Supply/Single Source
 2000 Continuous Water Supply/Multiple Source
 3000 Interrupted Water Supply/Single Source
 4000 Interrupted Water Supply/Multiple Source
 5000 Not Applicable (i.e. standing water source)
  100 Natural Water Source
   10 Flowing Water (more than 50 cfs)
   20 Flowing Water (10 to 50 cfs)
   30 Flowing Water (1 to 10 cfs)
   40 Flowing Water (.1 to 1 cfs)
   50 Flowing Water (.01 to .1 cfs)
   60 Flowing Water (less than .01 cfs or 4.5 gpm)
   70 Pond/Lake (greater than or equal to .1 ac/ft)
   80 Pothole (less than .1 ac/ft)
   90 Playa Lake
  200 Man-altered/Artificial Water Source
   10 Developed Spring
   20 Ditch (irrigation, drainage, stream channelization or diversion)
   30 Well
   40 Storage Tank
   50 Cistern
   60 Reservoir II (over 100 ac/ft)
   70 Revervoir I (10 to 100 ac/ft)
   80 Stocktank (less than 10 ac/ft)
    1 Nearest Perennial Source (more than 8 miles)
    2 Nearest Perennial Source (7 to 8 miles)
    3 Nearest Perennial Source (6 to 7 miles)
    4 Nearest Perennial Source (5 to 6 miles)

5 Nearest Perennial Source (4 to 5 miles)
6 Nearest Perennial Source (3 to 4 miles)
7 Nearest Perennial Source (2 to 3 miles)
8 Nearest Perennial Source (1 to 2 miles)
9 Nearest Perennial Source (less than 1 mile)
.1 Endangered Plant Species Present
.2 Endangered Animal Species Present
.3 Threatened Plant Species Present
.4 Threatened Animal Species Present
.5 Does Not Support Endangered or Threatened Species
.01 Ceremonial/Religious
.02 Domestic Use, Developed or Undeveloped
.03 Recreational Use (swimming, bathing, drinking, etc.)
.04 Agriculture and Livestock Use
.05 Fishing
.06 Aesthetics
.07 Outstanding Scientific Value
.08 Supports Riparian Vegetation
.09 Sediment Transport
.001 Ceremonial/Religious
.002 Domestic Use, Developed or Undeveloped
.003 Recreational Use (swimming, bathing, etc.)
.004 Agriculture and LIvestock Use
.005 Fishing
.006 Aesthetics
.007 Outstanding Scientific Value
.008 Supports Riparian Vegetation
.009 Only One Main Use
.0001 Water Quality Problem Present (public health level)
.0002 Water Quality Problem Present (non-public health level)
.0003 No Water Quality Problem
.00001 Problem Source Outside Natural Area
.00002 Problem Source Inside Natural Area
.00003 Problem Source Within and Outside Natural Area
.00004 Not Applicable
.000001 Biological Problem
.000002 Chemical Problem
.000003 Biological and Chemical Problem
.000004 Sedimentation Problem
.000005 Thermal Problem
.000006 Other Problem
.000007 Not Applicable

UNA CLASIFICACION QUE EMPLEA VALORES NUMERICOS PARA LOS RECURSOS DE AGUA LIQUIDA DE SUPERFICIE EN LAS AREAS NATURALES DEL SUDOESTE DE LOS ESTADOS UNIDOS

Un lógico primer paso en la administración de las áreas naturales de la región sudoeste de los Estados Unidos es un inventario sistemático de los recursos naturales a nivel local. Dado que el agua aprovechable es un mayor factor limitante como recurso en el sudoeste de los Estados Unidos, un amplio inventario de los recursos de agua sobre la superficie es de primordial importancia. Por lo tanto un sistema de clasificación práctica de agua de superficie es esencial para permitir el fácil almacenamiento de la información. La utilidad de la información acerca de los recursos de agua para el administrador de las áreas naturales es determinada principalmente por el método empleado para presentar esta información. En este caso un sistema apropiado de clasificación se convierte en un importante instrumento para la administración del recurso. Aún cuando el agua que existe como recurso en forma natural es el principal enfoque de este sistema de clasificación ella abarca asimismo varios acuíferos artificiales o acuíferos modificados. Aún las áreas naturales más grandes y más puras del suroeste de los Estados Unidos, tales como el Grand Canyon National Park en Arizona y para el cual fué elaborado esta clasificación, demuestra una variedad de modificaciones en sus recursos aquíferos.

Esta ponencia esboza una clasificación, para un recurso regional, la cual es aplicable a los acuíferos de superficie en estado líquido. La clasificación ofrece una banda amplia de las variables del recurso que serían útiles para el administrador a nivel local o regional. Se intenta relacionar la información del recurso agua asi tanto como otra información adicional que pudiera utilizarse como un inventario básico de los recursos de un área natural muy específica. La clasi-

ficación se creó para que fuera compatible con un programa de computadora. Esta clasificación es una jerarquía artificial y no natural (en contraste con una jerarquía natural con origen evolucionario) destinado para clasificación en el manejo del recurso y no como una agrupación natural de tipes de acuíferos sobre la superficie.

La clasificación en si comprende once niveles jerárquicos los cuales, en su conjunto se orientan a los parámetros físicos de tiempo y espacio, aspectos biológicos, características químicas y de calidad de agua y los usos principales del recurco. Para establecer la clasificación y la clave se combian los números para cada nivel jerárquico en una secuencia que forma un número de once dígitos. Los números que se ubican del lado izquierdo del punto decimal se aplican a los parámetros físicos de los recursos de agua de superficie mientras que los números del lado derecho del punto decimal representan otros valores de importancia subjetiva. Es posible introducir un cera donde se carezca de la información adecuada.

Los niveles individuales, empleando varias opciones en cada nivel, responden a las siguientes preguntas:

NIVEL 1	Es perenne, intermitente o efímera la fuente de agua?
NIVEL 2	Es contínuo or interrumpido?
NIVEL 3	Es natural o artificial?
NIVEL 4	Cual es el volúmen de agua que contiene y es agua que fluye or es agua estancada?
NIVEL 5	A que distancia se encuentra la fuente perenne más cercana?
NIVEL 6	Existen flora o fauna de especies apeligradas o amenazadas en el sitio?
NIVEL 7	Cual es su principal valor o uso?
NIVEL 8	Cual es su valor o uso secundario?
NIVEL 9	Existe o no ún problema en la calidad del agua?
NIVEL 10	De existir un problema, cual es la fuente de contaminación?
NIVEL 11	Cual es el índole del problema?

Asimismo esta ponencia presenta ejemplos de modificaciones al sistema para adaptarlo a los objetivos y a las necesidades de usarios locales.

Limits of Aerial Photography for Multiresource Inventories[1]

Robert C. Aldrich[2]

Abstract.--This paper reviews the qualities of aerial photographs in terms of resource information needs and makes recommendations for their use in arid land resource inventories. Photographic scales, films, formats, quality, and distortions are discussed in relation to recommended applications.

INTRODUCTION

Planning an inventory of natural renewable resources usually includes a choice of aerial photography to provide at least one level of inventory information. Sometimes this choice is limited to photography that is available. However, when new photography must be obtained, the choice of a film type, film format, and scale can be a frustrating experience in light of technical developments and conflicting reports during the past 15 years.

Selection of a photographic system and product for a resource inventory will depend upon the land and resource values (can they justify the cost), the inventory objectives, the information needs, and the budget. Aerial photographs might be used alone, with some ground sampling, or they might be incorporated in multiphase or multistage sampling designs.

This paper examines aerial photography in terms of the capabilities of photographic systems, inventory objectives, and the information requirements and makes recommendations for application in arid resource inventory.

CAPABILITIES OF PHOTOGRAPHIC SYSTEMS

A photographic system includes a camera and camera optics, a film, and a film format. The capabilities of photographic systems are usually measured in terms of their resolving power. The resolving power of a system depends on the film type, the quality of the camera lens, relative lens aperture, image motion, and the angular distance of the object from the optical axis of the camera.

Resolving power is generally measured in terms of the number of line pairs in a black and white bar target laid out on the ground that can be counted in one millimeter of an aerial photographic image. Resolving power at the center of the lens is better than at the margins of the lens. Most mapping cameras are capable of resolving 30 to 40 line pairs per millimeter. Some high altitude reconnaissance cameras on the other hand can resolve over 100 line pairs per millimeter. Generally speaking it is the film type, atmospheric conditions, and image motion, not the camera optics, that restrict the operational resolving power of a photographic system. One exception is the Eastman Kodak high definition films used in high altitude applications.

In operational situations we usually evaluate a photographic system in terms of ground resolution, i.e., the size of the smallest object that can be detected or measured on an aerial photograph. Ground resolution is a function of the photographic scale, the resolving power of the photographic system, and the magnification of interpretation and mapping instruments. Photographic scale is a function of the focal length of the camera lens and the flying height above the ground. The ground resolution required to measure an object must be approximately twice the resolution needed to detect the object (Welch 1972). Furthermore, the finest detail recorded on film today can only be observed using adequate magnification. In effect, magnification corresponds to a change in scale. Therefore, an evaluation of an aerial photographic system must include proper magnification of the images in mapping and interpretation instruments.

[1]Paper presented at the Arid Land Resource Inventories Workshop (LaPaz, Mexico, November 30-December 6, 1980).

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A vertical aerial photograph is a pictorial representation of a portion of the earth's surface at a particular time, however, an aerial photograph unlike a map, includes many distortions. Most distortions are geometric and are exaggerated by radial displacements of true image positions due to their height or elevation above or below some reference elevation (datum plane). Some distortions are caused by a nonvertical orientation of the camera at the time of exposure. All of these distortions are influenced by the lens focal length, the camera format size, and the height of the aircraft above the ground. For example, a 1:12,000 scale will result using a 6-inch (152-mm) focal length lens while flying at 5,000 feet (1785 meters) or using a 12-inch (305-mm) focal length lens while flying at 10,000 feet (3570 meters) above the ground. However, the photographs taken with the 6-inch lens will have objects displaced twice as far as the photographs taken with the 12-inch lens. For this reason 8½- or 12-inch lenses are recommended for large- and medium-scale aerial photography to avoid excessive elevational or geometric distortions on large format photographs (23 X 23 cm). These distortions can cause sampling bias and errors in area estimates.

Relief displacements (perspective geometry) are used to advantage in stereo models to measure object heights, elevations, and to produce contours and planimetric information on maps and orthophotos. On small format aerial photography (35 or 70 mm), a 6-inch (152 mm) or shorter focal length lens can be advantageous for large-scale sampling photography. Parallax is not too great for effective stereoscopic viewing and height measurements are readily made with parallax measuring devices. Radial displacement of images is reduced because a small format is comparable to looking at only the center portion of a large-format photograph where distortions are minimized.

It is important to remember that an aerial photograph is not a map and that the distribution of certain attributes of the land cover within the photograph are adversely affected by elevation. Because of this a first order map or orthophotograph is the best source of a sampling frame for resource inventory. An orthophotograph is a vertical aerial photograph that has been geometrically corrected so that images of ground objects are in their true orthographic position--much like a map. A sampling frame established on a map or orthophotograph can be transferred directly to the aerial photographs for interpretation and measurement. In the absence of maps or orthophotographs, however, sample points can be distributed on photographs free of elevational distortions using a stereoscopic plotting instrument and a sample pattern as a base map (Aldrich 1955).

Selection of the most suitable film type is important if inventory objectives and information requirements are to be met. Films today include panchromatic (BW), infrared (IR), color, and color infrared (CIR). The spectral sensitivity of BW and color films are very similar as are the sensitivities of IR and CIR. Panchromatic and color films are generally sensitive to the visible portion of the electromagnetic spectrum (EMS) from 0.4 μm (blue) to 0.7 μm (red). Infrared and CIR films are both sensitive to the visible portion of the EMS but the sensitivity is extended to about 0.9 μm to include some reflected infrared. It is also true that the resolving power of color and BW and CIR and IR films respectively, are very similar. However, proper filters must be used with these films to realize their full potential. For example, IR and CIR films are generally filtered with a minus-blue (Wratten 12) filter. Other filters such as a Wratten 25A (red) and a Wratten 89B (infrared) have been used with IR film to accentuate deciduous-conifer forest separations. Filters that cut out the blue and blue-green portions of the EMS have been successfully used to accentuate the orange-red portion of the EMS on CIR film.

GENERAL APPLICATIONS AND RESOURCE INFORMATION REQUIREMENTS

Applications of aerial photographs in natural renewable resource inventories can be separated into four broad categories: (1) classification and mapping the resource base, (2) interpretive information for specific applications, (3) measurement of resource variables, and (4) observation and counts of occurrences (Aldrich 1979a). Inventories are generally planned based upon objectives and information requirements falling within one or more of these groups.

Classification and Mapping the Resource Base

Classification and mapping applications involve delineations of homogeneous areas of land cover by either line drawing or point sampling. When areal and/or locational information is needed on vegetative or nonvegetative cover classes, land use, landform, or anomalies such as insect and disease outbreaks and vegetative cover and land use changes, aerial photographs are difficult to beat. More than 80 percent of the published use of aerial photographs fall in this category. It requires both interpretive and observational skills, as well as cartographic skills to accurately classify and map the sometimes subtle changes in cover classes. Boundaries between cover types can be drawn according to predefined criteria directly on the photographs or drawn on maps using mono or stereo zoom transferscopes. When maps are not required, large numbers of systematically arranged sample points can be interpreted and recorded in listings by categories to measure the distribution of cover types, compute areas, and provide strata for ground sample selections. If the photographic sample is intense enough, generalized maps of cover type can also result.

Large- and Medium-scale Photography

Large-scale color and color infrared (CIR) aerial photographs (1:600-1:10,000) are operationally feasible for many applications where the precise scale of the photographs is not important. For example, there have been many successful applications of large-scale 70 mm aerial photographs for insect and disease and tree mortality surveys carried out in a sampling framework. A 70 mm film format is recommended because it is amenable to use in small fixed-wing aircraft, it is large enough to sample sizeable areas of land, and it is convenient to view with a simple lens stereoscope while still in the roll.

Although large-scale color and CIR photographs (1:1600 - 1:2000) are recommended for vegetation species differentiation and could be useful in land cover classification, problems associated with scale variations, logistics, and cost make this photography difficult to use in resource inventories where precise measurements are required. They can, however, be useful to develop relationships between ground and photo cover classes found on medium- and small-scale aerial photographs. If and when sensitive radar or laser altimeters are feasible for small aircraft operations, measurement problems associated with aircraft altitude above ground (scale) will be resolved.

For mapping wetland and aquatic vegetation to the plant community level, 1:10,000 and 1:12,000 scale color and CIR have been found operationally feasible. Regardless of specific applications, large-scale aerial photographs are needed where ground resolutions of 0.3 meters or better are required.

Medium-scale (1:12,000-1:30,000) aerial photographs are recommended for most resource management activities. These applications include forest and range cover mapping, timber volume stratification, insect and disease surveys, wetland mapping to 1-hectare minimums, detecting and mapping disturbances, and soils mapping. With the exception of soils, CIR is the preferred film type. For soils mapping, a combination of normal color and infrared has been advantageous for associating soil color, landscapes, and drainage in soil delineations. Medium-scale aerial photographs will provide most natural renewable resource inventory information requiring ground resolutions between 0.3 and 1.5 meters (depending on the actual scale and the film type used). Stereoscopic instruments with magnifications of 1.5 to 2X are required to extract maximum information from the photographs.

Small-scale Aircraft and Space Photographs

When available, small-scale aircraft and space photographs (1:40,000-1:200,000) will provide most of the information obtainable from medium-scale photographs. Depending on the actual scale and film type used, most forestry information needs requiring a ground resolution between 1 and 4 meters will be satisfied. However, stereoscopes and photo transfer devices with 3 to 9X powered optics will be required to maximize the information that can be extracted. Color infrared (CIR) film is the most useful film type for vegetation and water classification and mapping. On CIR, broad forest and range vegetation classification including distinctions between coniferous and deciduous forest stands and grasslands, and some distinctions within these groups, are possible. Generalized soils mapping has also been successful on high-altitude panchromatic photographs.

When using small-scale imagery of any kind, the problem of legend size and minimum areas must be overcome. Delineating cover class boundaries directly from the photographs onto larger-scale maps is probably the best solution for mapping when minimum areas are less than 10 acres (4 hectares). However, having the photographs enlarged as much as 4 times can also be helpful for mapping small areas.

Very Small-scale Space Photographs

Very small-scale photographs from the Apollo 9 (1969) and the Skylab (1973) space missions (1:500,000-1:4,000,000) have advantages for delineating broad forest and nonforest land classes for extensive areas. Reduced distortions from topographic relief displacements, broad synoptic views, low cost of the photographic data, and reduced effects of shadows make photographs taken from space highly desireable for classification and mapping. High definition panchromatic and color (over 100 line pairs per millimeter) and improved CIR are recommended films. Nonstereoscopic viewers and instruments with magnifications of 13 to 60X are needed (with zoom capabilities) to classify and map from the smaller images. An investment of from 5 to 20 thousand dollars in photogrammetric instruments would be required to properly utilize these images. Although these types of photographic data are not being acquired at the present time, earth orbiting satellites scheduled for the 1980's should once again make synoptic space photographs available.

There is a very real and potentially profitable use of the very small scale space photographs in the application of microdensitometry and computer aided classification for acquiring resource information in a digital format. Digitized photographic data at these smallest scales would have a better ground resolution than current nonphotographic satellite data (Landsat). However, the shorter dynamic range in photographic spectral data and limitations due to photographic image brightness and atmospheric interference variations, as well as camera optics and film emulsion differences, make the use of film density measure-

ments difficult and unreliable at the present time.

Interpretive Information for Specific Applications

Information interpreted from aerial photographs in the sense used here does not result in a map. It might confirm that a certain condition exists, locate and flag the condition, and provide certain corollary information needed to manage the condition. Some examples of interpretive information are the location of unusual vegetation stress, a potential landslide, a geological hazard, soil erosion, an oil slick, and other water or air pollutants. These applications will require some observational and measurement skills to interpret the conditions that exist.

Large-scale aerial photographs can be used to monitor environmental conditions within high value areas such as campsites, parks, or along roadways. Smog damage, impact of grazing on streams and meadows, stream channel stability and alterations, grazed and ungrazed areas within a single vegetation complex, wildlife habitat trends and related vegetation and hydrologic changes, and streat trout habitat conditions have been monitored with large-scale 70 mm color and CIR photographs. Preferred photographic scales for these applications range from 1:600 to 1:8,000 and depend on the wildland condition to be interpreted.

Interpreting man's impact on roadway environments can be derived from medium-scale photographs. This is particularly true if the need is to determine the location of existing powerlines and manmade developments. Color infrared and color films at scales of 1:12,000 to 1:20,000 are advantageous to assess manmade impacts because of the increased differentiation between small variations in the ground objects. Previsual stress in some angiosperms but not gymnosperms can also be detected on IR and CIR films.

Geologic hazards associated with earthquake damage, landslides in areas of unstable slopes and subsidence, and flowage of surface materials in areas underlain by sands are interpreted from CIR transparencies. The disrupted drainage and vegetation are shown more clearly on CIR than on other films. Surface configurations and textural patterns on exposed bedrock are emphasized by shadows and moisture in depressions on infrared photographs. Although photographic scales larger than 1:10,000 are preferred for these details, both medium- and small-scale aerial CIR have been found useful for detection of gross geologic structure and hazard conditions and are available more often than larger scales.

Archaeologists have found that CIR film is preferred for detecting and outlining subsurface details such as buried foundations. Both color and CIR are preferred for detecting soil marks and certain crop or plant marks caused by underground or surface anomalies. Although scales of 1:10,000 to 1:20,000 have been successful, the literature indicates that 1:3000 to 1:10,000 are usually preferred. Multiband photography has been useful for archaeology because it increases the capability to detect archaeological sites by comparing film and filter combinations simultaneously for the same area.

Measurement of Resource Variables

Both heights and linear measurements are most accurate on large- and medium-scale photographic scales (1:600-1:30,000)--particularly when the photographic scale can be accurately measured. Height or slope measurements are unreliable on photographic scales smaller than 1:100,000 because parallax differences are so small that they can be completely masked by "play" in the micrometers of most measuring instruments. Most improvements in photo measurements will result from the use of large-scale photographs, more efficient sampling designs, and improved measuring instruments--the basic concepts and techniques have remained the same and are well documented in photointerpretation text books (Spurr 1963; Avery 1977).

Scale variations can be a serious problem when using large-scale photographs for measurements. The larger the scale the more serious the problem. Small variations in flying height above the ground make a significant difference in both parallax differences and linear and area measurements. The most useful variables for estimating tree volumes on aerial photographs are tree height, crown width, and crown area. If the photograph scale can be determined, the most accurate measurement of these variables can be made on normal color transparencies at normal color transparencies at scales between 1:1600 and 1:4000. When scale variations are accounted for, tree heights are measured within ± 3.5 feet and crown diameters within ± 2 feet. In practice, large-scale 70 mm sampling photographs are most effective when applied to inventories of large relatively inaccessible areas that sometimes require use of aircraft for ground access.

In range inventories, percent cover can be obtained for recognizable species on large-scale aerial color and CIR photographs (1:600-1:4000) in a significantly shorter time than by conventional field methods using larger sample sizes. Density, or number of plants per unit of area, however, cannot be extracted by species.

Water depth, or distance penetration of masses of water, can be measured on multilayer photographic materials--either bicolor or tricolor films--in bands properly selected to take advantage of spectral absorption and scattering properties of water. Furthermore, photointer-

pretation keys for water quality can be developed for distilled water, clear lake water, sedimentation, and algae to use with aerial color and CIR films to classify lakes.

Observations and Counts of Occurrences

Generally speaking, the detection and evaluation of structures and transportation, communication, and utility systems, and vehicle and population counts within wildland environments require photographic imagery with ground resolution capabilities of from 0.3 to 15 meters. Although available photographs are used when possible, CIR is the most effective film type for making observations of the type desired. To obtain detailed information about individual structures and properties, a photographic scale of 1:5,000 or larger is required. To observe and count ski-slopes, parking lots, boats, marinas, and the wakes of boats, scales as small as 1:120,000 have been successful. However, accurate counts of vehicles and people require much larger scales. People counts require a 1:2000 scale or a capability of 0.1 meter ground resolution.

Inventories of livestock and large game can be made on panchromatic film exposed with a Wratten 12 (yellow) filter. The scale of the imagery must be larger than 1:5000 to be effective. Photography must be taken a few hours after sunrise or a few hours before sunset to capture the animals before they seek shade. In arid regions the best time of year is early spring after the winter rains and before shallow soils dry out causing the vegetation to "brown up."

Some animals can be detected and counted by using the proper portion of the EMS to accentuate the animal-background difference. For example, harp seal pups are detected using ultraviolet photography. The pup's white fur absorbs ultraviolet energy while the background of snow and ice reflects ultraviolet--the pups stand out as dark objects against a white background.

AERIAL PHOTOGRAPHY FOR ARID LAND INVENTORIES

The limits of aerial photographs in arid lands inventories differ from limits elsewhere only by the level of application. Level of application is a function of the land values (uses), management's information needs, and the budget. The latter is a function of land values--the greater the value (tangible or intangible) the greater the management need and the more the cost of aerial photography can be justified. The capabilities and general applications of aerial photographs described elsewhere in this paper apply to all lands. However, because arid land values are generally unknown and more difficult to assess, and because they are more often categorized as marginal, low value, wastelands, or barren it would seem appropriate to address them with some reservation. For example, final recommendations for aerial photography should wait for an evaluation of the multiresource values (timber, range, recreation, wildlife, and water) and an assessment of management needs for information to answer questions regarding these resources.

Information Needs

Aerial photographs will furnish certain basic information to satisfy multiresource inventory requirements. These information needs have been translated into inventory data elements that are common to all resource systems (Aldrich 1979b, 1979c) and should apply to arid lands as well as other lands.

1. Horizontal distribution of cover. This element includes the cover type (vegetated or nonvegetated), size, shape, distance to cover change, number of cover changes, uniformity of cover, and distance to water. These variables apply to both wildland and developed land and to water, snow, and ice.

2. Biomass. In addition to the area covered by a type of vegetation this element includes the mean height of canopy, mean height of understory, canopy closure, understory closure, ground cover, exposure (slope and aspect), and spectral ratios.

3. Landform. This element includes only the local level of landform classification heirarchy. The variables for observing landform, and the area they influence have not been defined.

4. Mortality. This element can be observed and measured by tree counts and/or area affected.

5. Vertical distribution of cover. This element includes both vegetated wildland (over 2 percent closure) as well as vegetated developed land. Basic photographic variables are mean vegetation heights, tallest tree, shortest tree, number of vegetation layers, mean height or layers, stand size, number of trees, and area by cover class.

6. Volume (timber). Many variables for biomass estimation are also variables for volume. These include mean stand height, crown closure, crown diameter (mean), largest crown diameter, smallest crown diameter, crown area, number of trees, and area by cover type.

7. Forage. One of the more difficult to quantify elements, forage can be estimated using cover type, area of cover type, species composition, canopy closure, and spectral ratios. In open rangeland, however, particularly in the arid areas of the world, the quantification of forage may not always be possible. This is because the higher reflectance values from soil and rock backgrounds may mask out the lower reflectance values from grasses, forbs, and other vegetation--particularly when the area is less than 40 percent

vegetated and small-scale aerial or very small-scale space photographs are used.

8. Changes (disturbances to cover class over a period of time). Changes are important to all resource systems and are detected and/or measured by temporal and/or seasonal differences in spectral data and by the area they affect.

Potential Applications

Keeping in mind the eight basic types of resource data elements obtainable from aerial photographs, two applications seem to have greater potential for arid land inventories than others. These are to establish a resource data base as an aid to land management and then to monitor the established resource data base for changes.

Establishing a Resource Data Base

A resource data base can be established in many ways. Probably the simplest way is to map the area in question directly on aerial photographs. To be most efficient, cover classes should be mapped to the lowest level in a classification hierarchy required for management purposes. Mapping to any higher level than necessary is expensive and the unnecessary detail can sometimes be more of a hindrance than a help. Mapped polygons are labeled and a file number is assigned. Cover classes, additional photo interpreted information, and any ancillary information are stored for recall when needed. Recognizing that aerial photographs have inherent distortions, they can be removed from the files along with other information and used as maps in the field. However, if distortions are too great or a map record is required, the photo delineations can be transferred to available maps using overhead projectors, transferscopes, or by more sophisticated mapping instruments. Photo information can be very useful to the land manager in either of these forms.

Minimum requirements for aerial photography to map the resource base are given in table 1. These requirements are generalizations and should be accepted only as a guide. Before deciding on new photography several questions should be seriously considered. For instance, what level of classification is required for the assigned task? Do you need species specific information or is a broad classification adequate? What accuracy do you need and what minimum area is acceptable? Answers to these questions and others can be very helpful.

Cover class definitions can be very helpful in selecting proper photography. For example, in table 1, the classification level "Grassland-shrubland" is defined as an area where grass composes more than 50 percent but less than 70 percent of the vegetative component. Shrubs occupy the remainder of the area. This definition is restrictive because it requires at least a 1:20,000 scale CIR photography to map to this detail. If, however, the manager's needs are satisfied with merely a breakdown of "Tree covered" and "Nontree covered" vegetation classes, high altitude photographs at 1:184,000 scale should suffice. Color infrared is recommended for most classification in arid lands because of its better contrast between vegetated and nonvegetated areas, differentiation of surface water or wet areas (wet meadows and riparian vegetation), detection of stressed vegetation (due to seasonal or non-seasonal drought conditions), and detection of soil movement (erosion or landslides). Soil classification, however, can be aided best by the use of normal color photographs in combination with high altitude panchromatic photographs.

Monitoring the Resource Base

What happens to the resource area base over time is a very important inventory requirement. It is particularly important in the years ahead as the natural renewable resource area base shrinks, the world's population increases, and the demands on remaining wildland areas become greater.

Change can be monitored using aerial photographs taken at intervals of 2 or more years--the frequency of coverage depending upon the amount of development in the area and the land and resource values. Areas within the influence radius of high population centers will require monitoring (reinventory) at more frequent intervals than more inaccessible low population density areas. The total change can be mapped by interpreting two dates of photography simultaneously. Estimates of change can be made by observation of large numbers of permanent photo samples located systematically or randomly throughout the two sets of photographs.

Small-scale aerial or very small-scale space photographs are recommended for monitoring the resource base for change. Problems associated with flight line orientation on two dates, photo coverage, time of day (shadow direction and length), and the season of the year are minimized on the synoptic smaller scale photographs. Color infrared is recommended because even the slightest disturbance to the surface of the soil (usually associated with changes made by man) show up on this film. The scale and film type used, however, should be coordinated with other inventory requirements to make most effective use of the film. One solution might be to use two cameras on a single photographic flight mission to obtain two types and two scales of photography that will satisfy most inventory objectives. An example of this is the 1:80,000 panchromatic and 1:60,000 CIR currently being flown under contract for several agencies of the U.S. Government.

Even though a change is detected, the cause of change is not readily interpreted from small- or very small-scale photographs. This is par-

Table 1.--Minimum requirements for aerial photography to classify and map land cover to 10 acre (4 hectare) minimum.[1]

Cover class level	Required resolution (m)	Recommended film types	Minimum scales	Magnification	Platform
*Land Water	10-30	CIR[2] IR[3]	1:500,000- 1:1,500,000	20-45 X	SAT
*Vegetated Nonvegetated	10-30	CIR[2]	1:500,000- 1:1,500,000	20-45 X	SAT
*Wildland Developed land	10-30	CIR[2]	1:500,000- 1:1,500,000	20-45 X	SAT
Tree covered *Nontree covered	1.5-3.0	CIR[2,4] BW[5]	1:64,000- 1:184,000	3.5-8.5X	HAP
Tundra *Nontundra	0.5-1.5	CIR[4]	1:20,000- 1:64,000	1.5-3.5X	MAP, HAP
Pure *Mixed	0.5-1.5	CIR[4]	1:20,000- 1:64,000	1.5-3.5X	MAP, HAP
*Upland Bottomland Wetland	0.5-1.5	CIR[4]	1:20,000- 1:64,000	1.5-3.5X	MAP, HAP
Forb-grassland Grassland-forb *Grassland-shrubland Forb-shrubland	0.3-0.5	CIR[4] Color[6]	1:12,500- 1:20,000	1.5X	MAP

[1]Land cover classes taken from Aldrich, Robert C. and Richard J. Myhre, "A preliminary key for photo interpretation of land cover with specific reference to Kershaw County, South Carolina." USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo. 54p. In preparation.

[2]Eastman Kodak High Definition Aerochrome Infrared SO-127

[3]Eastman Kodak Infrared Aerographic 2424

[4]Eastman Kodak Aerochrome Infrared 2443

[5]Eastman Kodak High Definition Aerial 3414

[6]Eastman Kodak Aerochrome MS 2448

ticularly true in tree covered areas. However, in nontree covered lands, more typical of arid lands, the cause of changes may be more readily interpreted.

There are three kinds of change inventories. There is the periodic reinventory of resources for management information. These periodic reinventories of renewable natural resources are usually conducted using permanent sample plots with or without partial replacement. Permanent photographic sample plots that include photo-ground plots can be useful to improve estimates of land use and cover class area changes and to quantify changes in phytomass. Expensive permanent ground plots can be reduced by developing probabilities of change from photo-ground relationships--the lower the probability of change the fewer samples are required on the ground. A second kind of change inventory is a system to monitor and locate and measure areal changes. Areal changes and the location of changes can be important to the local manager in his day to day operations. One such change in arid lands might be the encroachment of desert upon arable land caused by poor land management. Knowing how much and where desertification is occurring can be helpful toward eliminating the problem. The third and last kind of change inventory is to monitor condition changes (anomalies) associated with land use--timber, range, wildlife habitat, recreation, etc. Condition changes associated with land use include not only the problem of desertification but insect and disease outbreaks, over grazing of range, grazing and streambank erosion, changes in wildlife habitat that might threaten endangered species, recreational impacts such as off-road vehicle damage, and others.

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RESUMEN

Para todos los recursos o inventarios extensivos de riquezas naturales, y para muchos inventarios intensivos de las mismas, la fotografía aérea es una herramienta indispensable. La fotografía aérea es una base de información de recursos naturales que puede ser utilizada para el manejo o administración de las actividades del terreno; una base de información para el costo de diseños de pruebas estadísticas eficientes; y una base de evaluaciones periódicas de los cambios que ocurren en el suelo. Las fotografías contienen información de una extensión aérea sobre la cantidad y la calidad de los recursos naturales renovables en un tiempo determinado.

Para poder obtener la mayor información de la fotografía aérea, el usuario debe de tener conocimiento de principios básicos de medidas fotográficas, entender como las distorciones de evaluación o geométricas pueden afectar la información contenida en un mapa y por lo tanto, el resultado de los recuentos o inventarios, y saber como calcular las cualidades espaciales (resolución) y espectrales de películas fotográficas y las escalas apropiadas para sus necesidades específicas.

Usos de la fotografía aérea para los recuentos o inventarios de recursos naturales renovables son presentadas bajo cuatro amplias categorías: (1) Clasificación y trazo de mapas que se usarán de base de información de recursos. (2) Interpretación de la información para usos específicos. (3) Medidas para las variables de dichos recursos. (4) Observación y conteo de sucesos. Generalmente, la escala amplia (1:500-1:12.000) de color o color infrarojo en fotografías se requiere cuando el detalle del suelo del cual se piensa trazar un mapa, medir u observar, es de 0,3 metros o más pequeño en tamaño. Arboles y especies de plantas del campo o serranías, comunidades de plantas, daños causados por insectos o enfermedades son interpretados; los árboles y la vegetación vecina son medidos por la masa biológica y el volumen de la madera con la mayor precisión. Escalas media (1:12,000 - 1:30,000) son recomendadas para trazar mapas usados para el manejo de actividades que incluyen bosques, campos y pantanos o terrenos cubiertos con agua; volumen de los estratos de madera; inspecciones de enfermedades e insectos; para detectar y trazar mapas de disturbios y hacer mapas del terreno. Películas de color infrarojo se prefieren para la mayoría de las situaciones en que se usa la escala media. Para el trazo de los mapas del terreno sinembargo, una combinación de fotografía a color normal e infrarojo es lo mejor. La información necesaria requerida para 0,3 a 1,5 metros de resolución para detalles del suelo, pueden ser obtenida usando la escala media. El uso de aviones y fotografías espaciales (1:40,000-1:200,000) pueden ser muy útiles para hacer recuentos de recursos que requieren ver detalles en el suelo a una medida de 1 a 4 metros. En este caso, el color infrarojo se prefiere a otras películas para trazar mapas de amplias clases de foresta, vegetación y de agua. Se ha trazado mapas de terrenos a un nivel de trazo general con la ayuda de fotografías pancromáticas a escala muy pequeña y desde una altitud muy elevada.

Aunque no facilmente disponible en la actualidad, una escala aún más pequeña (1:500.000-1:4.000.000) de fotografías infrarojas a colores tomadas desde el espa-

cio, debido a su abarcamiento tan general, puede resultar muy efectiva para el amplio trazo de mapas de vegetación, uso de la -tierra, clases de agua y para detectar -- cambios relacionados con el uso del terreno.

Fotografías aéreas son recomendadas para hacer recuentos o inventarios de terrenos áridos y establecer y controlar la base de información para los cambios que puedan ocurrir. Es importante conocer el nivel de las jerarquías de clasificaciones en la base de información para poder seleccionar la película apropiada y la escala para el trazo de mapas. Cuando es posible escoger, se recomienda la película de color infrarojo tanto para el trazo de mapas como para el control de los cambios. Una tabla está incluída como guía para el usuario para ayudar con la selección del tipo de película, escala, e instrumento de magnificación para trazar mapas a varios niveles dentro de la clasificación que cubre la tierra o suelo. Escala aérea pequeña (1:40.000-1:200.00) y una más pequeña (1:500.000-1:4.000.000) es recomendada para llevar un control en los cambios de la base de información.

Landsat: a Sampling Frame for Arid Land Inventories[1]

William J. Bonner, Jr.[2] and John Morgart[3]

This paper describes how Landsat and ancillary data were utilized to obtain natural resource inventory information about the unit. In this paper, emphasis is placed upon the inventory requirements, an accompanying paper shall describe the methodology applied. Inventory requirements are discussed and various products for meeting these dictates are described. The approach is shown to be applicable to other areas of a similar environment. Cost per unit area is discussed and the economy of doing larger areas within the same environmental strata is cited.

1.0 Introduction

The Bureau of Land Management (BLM) of the United States Department of the Interior (DOI) is responsible for the multiple use management of the natural resources on 191 million hectares of public lands in the arid to semi-arid western United States of America (USA). Management of such a vast area requires development and maintainence of a resource inventory base. This inventory base must be reliable, easily updated, and readily accessed. For this reason, BLM has been investigating the applicability of remote sensing data for obtaining inventory information. This paper addresses one aspect of that investigation - the use of Landsat as a sampling frame for inventories.

1.1 Arizona Test Site

This project was conducted in the Southwest USA in the State of Arizona. The one million hectare area represents a southwestern desert community. Figure 1-1 illustrates the location of the project. The area is characterized by broad valleys separated by hills and mountains. The topography and latitude support a climate with light precipitation, moderate to high temperatures, plentiful sunshine and low humidity. Mean annual precipitation ranges from about 13 cm along the Colorado River to 46 cm in the Virgin Mountains. About half of the annual precipitation occurs from December through March and is produced primarily by storms from the Pacific Ocean that have entered the continent along the southern California coast. Occasional snows occur at the higher elevations during the winter months and temperatures typically range from 9° C to 17° C during the afternoon and drop to freezing in the evenings. Summer temperatures range from 31° C to 42° C and are accompanied by low humidity. The area ranges in elevation from about 300 m to 2500 m.

Vegetation in the area varies from creosote bush (Larrea divaricata) and blackbrush (Coleogyne ramosissma) at the lower elevations to pinyon-juniper (Pinus sp., Juniperus sp.) and ponderosa pine (Pinus ponderosa) at higher elevations. The area provides important habitat for a wide variety of wildlife including

Figure 1-1

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[1] Paper presented at the international workshop, Arid Land Resource Inventories: Developing Cost-Efficient Methods, November 30 - December 6, 1980, LaPaz, Mexico.

[2] Division of Scientific Systems Development, Bureau of Land Management, USDI, Denver, CO.

[3] Arizona Strip District, Bureau of Land Management, USDI, St. George, Utah.

Hierarchical Vegetation Classification Framework for the Arizona Strip District Test Site

Level I (Biome)	Level II (Formation)	Level III (Association)	Level IV (Community)
4 Shrubland	1 Mohave desert shrub	1 Riparian desert shrub	1 Mesquite-acacia
			2 Tall rabbitbrush
		2 Upland desert shrub	1 Creosote
			2 Bursage
			3 Yucca
			4 Mixed desert shrub
	2 Great Basin desert shrub	1 Great Basin sagebrush	1 Big sagebrush
			2 Big sagebrush-perennial grass
			3 Big sagebrush-mixed shrub
			4 Big sagebrush-tree
		2 Saltshrub	1 Shadscale
			2 Fourwing saltbush
		3 Blackbrush	1 Blackbrush
			2 Blackbrush-tree
			3 Blackbrush-other desert shrub
		4 Other tall shrub	1 Cliffrose
			2 Winterfat
			3 Tall rabbitbrush
		5 Half shrub	1 Snakeweed
			2 Little rabbitbrush
	3 Mountain shrub	1 Mountain chaparral	1 Manzanita
			2 Mixed chaparral
		2 Oakbrush	1 Gambel oak
			2 Turbinella oak
			3 Mixed oak
		3 Other mountain shrub	1 Serviceberry-ceanothus
			2 Mixed mountain shrub

Figure 1-2

mule deer (Odocoileus hemionus), antelope, (Antilolapra americana) and desert big horn sheep (Ovis canalensis). Domestic cattle are major users of the area resources.

1.2 Objectives

The objectives of this project were two fold. First it was desired to test Landsat as a sampling frame for mapping of land cover units to a classification framework level II and III as shown in the example in Fig. 1-2.
Secondly the program tested the ability of Landsat to serve as a sampling frame for inventories of rangeland, forest, and woodland resources. The former task was accomplished as a joint effort between BLM and the EROS Data Center (EDC) Sioux falls, South Dakota. The latter effort was done under a contract with ESL, Inc. of Sunnyvale, California. The contract was administered by the National Aeronautics and Space Administration (NASA) as part of an Applications Project Test (APT) with BLM.

2.0 Operational Methodology

2.1 Multistage Sampling

The term "multistage sampling" in remote sensing literature has frequently been applied to a technique in which several levels of remote sensing data have been acquired over the same area. For example, low level aerial photography (large scale), high level aerial photography (small scale), and spacecraft (synoptic scale) are all collected over a given study site. However, the terminology "multistage variable probability sampling" refers to a specific set of statistical procedures which employ various levels of remote sensing data to make measurements or estimates of a resource parameter from sample units which are combined to produce a regional estimate of that parameter. Examples of parameters are timber volume, acreage, and forage production. This process is known colloquially as "multistage sampling", and is illustrated in Figure 2-1.

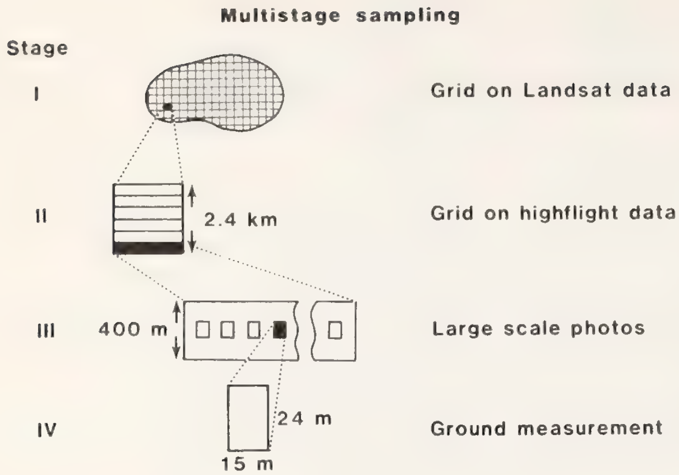

Figure 2-1

2.1.1 Historical Perspective

The first application of "multistage sampling" procedures to use spacecraft data was a study by Langley (1971). Timber volume estimates for a large area in Louisiana, Mississippi and Arkansas were made using ground plots, two levels of aerial photographs, and one color infrared Apollo 9 space photo. Nichols, et al, (1973) used these procedures to estimate timber volume within a mixed conifer type on the Plumas National Forest in northern California. In this program Landsat, low altitude aerial photographs, and ground plots were utilized. Following the example of applying "multistage sampling" in forest inventory, researchers at the University of California at Berkeley, DeGloria, et al, (1975), modified the procedures to estimate forage production in a rangeland environment. This study was conducted for the BLM in northeastern California. Estimates of forage production were generated from ground plots, two levels of aerial photographs, and Landsat stratification. This project led directly to the investigation on which this paper is based.

2.2 Sampling Techniques Utilized

This test project was divided into two phases. The initial phase concerned itself with using Landsat as a mapping base for acquiring land cover mapping information and was oriented toward producing acreage estimates and species composition descriptions. The second phase was directed toward determining inventory data for forests, woodlands, and rangelands. In this latter phase, estimates of production for volume of timber, volume of woodlands, and available forage from rangelands were made.

2.2.1 Stratified Cluster Sample

A stratified cluster sample was utilized in the mapping effort. Classified Landsat data were grouped into land cover strata and these strata were utilized as a sampling frame for allocation of 23 x 23 cm, 1 6000 scale, color photographs. On each photograph a sample unit (SU) was defined as an 8 x 8 picture element (pixel) grid. Each cell in the 8 element by 8 line grid was defined as a photo plot on which detailed photo interpretation data were recorded.

A stratified cluster sample was also utilized in the rangeland inventory phase of this project. In this case classified Landsat data were once again grouped into resource cover strata but in this case the strata were then sampled with ground plots.

2.2.2 Two Stage with Double Sample

A two stage with double sample approach was used in the inventory effort for woodlands and forests. In this approach Landsat was utilized for stratification and samples of 35 mm strip photography were collected within the Landsat strata. The 35 mm transect at a scale of 1·1000 formed the secondary sample unit (SSU) and each SSU contained 15 stereo photo plots. From a selected number of SSU's a number of the photo plots were selected as tertiary sample units (TSU) to be visited on the ground.

2.3 Land Cover Mapping

As mentioned previously the purpose of the mapping aspect of this program was to generate level II and III cover type detail (Figure 1-2). In addition, it was desired that the final map product be cartographically correct and provide additional detail beyond that given by each land cover class. In order to achieve the foregoing, certain steps were taken in processing the Landsat digital data. For example, appropriate geometric and radiometric corrections were made to remove inherent errors in the Landsat system. Examples of corrections are mirror scan velocity profile, earth curvature, and destriping. In addition, the Landsat data were registered to a 50 meter Universal Transverse Mercator (UTM) grid. Administrative boundaries were digitized. Information relating to ownership, allotments, and pastures was thereby incorporated with the Landsat data. Finally digital terrain data was utilized. Elevation information from the digital terrain tapes was then also used to calculate slope and aspect. The entire data set was then joined with the

Table 2-1 Allocation of Sample Units to Strata

Landsat Strata	Area (Hectares)	Sample Units (Allocated)	Sample Units (Acquired)
Agricultural	1 681	3	3
Barren	50,345	7	5
Cold Desert Shrub	467 182	72	56
Coniferous Forest	4,547	3	3
Deciduous Woodland	374	2	2
Evergreen Woodland	158 200	24	19
Grassland	76 053	11	7
Hot Desert Shrub	148 017	22	22
Mountain Shrub	2 833	3	2

Landsat classification results to establish a digital data base which is the final product from this type of study.

2.3.1 Allocation

The sampling for this effort was a stratified cluster sample, Rohde, et al., (1980). Cluster sample units were allocated to each Landsat strata using proportional allocation with respect to area. A total of 147 sample units were allocated on this basis to 9 Land Cover Units as illustrated in Table 2-1.

The total number of sample units were constrained by the resources available to the project. For example a fixed amount of money was available for aerial photography, and a limited number of work months were available to perform photo interpretation of the photographs collected. Such limitations determined the total sample size. Also shown in Table 2-1 is the fact that in reality only 119 samples were actually collected. This was due to an extended period of inclement weather in the project area which prevented photo acquisition of all 147 plots allocated. The photo samples (sample units) were collected as stereo triplets in color at a scale of 1:6000 in a 23 x 23 cm format. Each photo was divided into an 8x8 pixel cluster. Figure 2-2 illustrates the stratified cluster sample.
Then each individual pixel (photo plot) was photo interpreted to level IV of the classification framework. The level IV calls were subsequently entered into the Landsat data base by line and sample for each pixel. During the course of the project it was determined that the scale of the photography was not optimum. Indications are that 1.3000 scale photography stratified as 3x5 cluster samples would better suit the interpretation requirements of such a project. A total of 119 sample units, each containing 64 photo plots were collected and interpreted; thus, a total of 7,616 photo plots were interpreted to describe the Landsat classification.

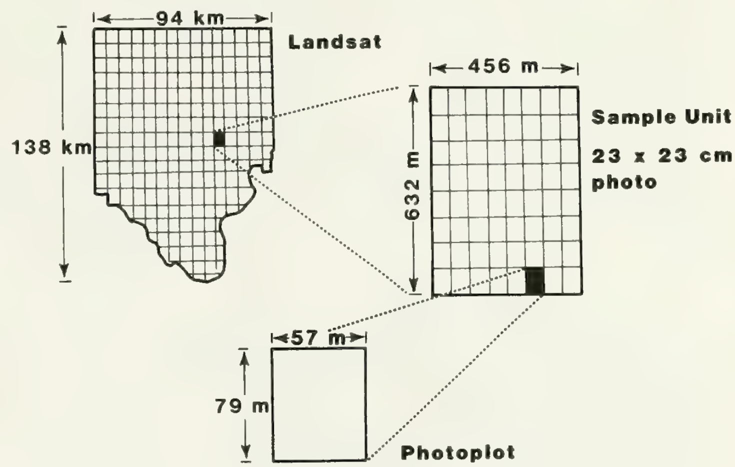

Figure 2-2

2.3.2 Digital Terrain Data

Digital terrain data were acquired for the project area from the National Cartographic Information Center (NCIC). The digital terrain tapes were then joined by coordinates to the Landsat data base. Table 2-2 illustrates a set of decision rules which were utilized for reclassification of the Landsat data. Incorporation of this data greatly enhanced the final classification results. In addition to elevation, slope and aspect data were also utilized in the analysis. Slope and aspect were calculated from the elevation information.

2.3.3 Classification

Classification of the Landsat data was achieved using a "controlled clustering" approach, Rohde (1978). In this approach polygonal shaped training areas containing several resource types were selected by the analyst. Pixels

Table 2-2 Example of Elevation Decision Criteria

Cover Type	Elevation Decision Criteria (Meters)	Revised Cover Type
Cold Desert Shrub	≤822 823 - 1737 1738 - 1981 >1981	Hot Desert Shrub Cold Desert Shrub Evergreen Woodland Mountain Shrub
Evergreen Woodland	≤822 823 - 1371 1372 - 2103 >2103	Hot Desert Shrub Cold Desert Shrub Evergreen Woodland Ponderosa Pine

within these training units were grouped into a number of spectral clusters which were displayed via a color monitor. The analyst then identified the resource cover types associated with each cluster using aerial photographs, ground data, and other supporting information. Once this was accomplished a standard maximum likelihood classification was applied using the training statistics on the entire data set.

2.3.4 Output Products

Although a number of different types of maps, overlays, tables, etc. can be produced in this type of project the real and final product is in fact a digitized data base. From this set of information any product which is describable in terms of the data base can be produced.

2.4 Inventory of Forest, Woodlands and Rangelands Resources

A major effort in this project was directed toward evaluating the use of Landsat for inventories of forest, woodland, and rangeland resources. In order to determine the exact sampling requirements for such a project and to better define the role of Landsat in such an effort, a pilot study was conducted in the Arizona Test Site during the summer and fall of 1978. The pilot study considered the use of Landsat, aerial photographs, and ground plots in a two stage with double sampling scheme. Air photos were investigated for the practicality of interpreting species of grass, and other related parameters for rangeland inventory. In addition, several interpretations concerning woodlands were investigated (e.g., descrimination between pinyon and juniper). It was concluded that a two stage with double sample approach was feasible for woodlands and forests but not for rangelands. A sample consisting of a Landsat stratification and ground plots was recommended for rangelands. The pilot study was conducted because sufficient information about rangeland applications of multistage sampling was not available to researchers at the initiation of the program. A pilot study would not be required for future inventories.

In a manner similar to that described in section 2.3 Landsat data were processed. Geometric and radiometric corrections were applied. A mixed supervised/unsupervised classification technique was used. In this case large scale 35 mm photo plots were acquired within the Landsat strata. Digital terrain data were also utilized in the reclassification process. Due to funding limitations only a representative portion of the entire project area was inventoried. In all, approximately 200,000 hectares were processed for production information.

2.4.1 Allocation

The University of California Berkeley (UCB) Survey Planning Model (SPM) was used to determine sample sizes for estimating cattle-usable forage biomass in the rangeland stratum and wood volume in the forest and woodland strata. The SPM utilizes a nonlinear programming procedure for finding the number of samples to be allocated. These samples are allocated between substrata and sample stages to minimize total variable cost (subject to meeting prior constraints on sampling error for the parameters to be estimated). Allocation was based on a sampling error goal of ± 20% for total cattle usable forage biomass at the 80% confidence level at the strata level. In other words, the true value for the estimated parameter was to fall within ± 20% of the estimated value, 80 times out of 100, Gialdini (1980). Table 2-3 shows the results dictated by the SPM for allocation of large scale photo plots and ground plots.

Table 2-3
Survey Planning Model
(Allocation)

Cover Type	Landsat Strata (Class Number)	PSU's (Total)	SSU's (Photo)	TSU's (Ground)
Woodland	14	96	45	4
	15	168		6
	16	122		6
	17	1		0
Forest	20	11	4	4
	21	447	26	15
	22	32	17	10
Rangeland	1	761	15	18
	2	104	4	6
	3	70	4	6
	6	72	4	6
	8	6	4	6
	17,18	19	4	6
	9,12,27	722	15	18
	10 13	280	8	10
	11	104	8	8
	14	208	8	10
	15	513	10	12
	16	380	8	10
	21	5	4	6
	23	8	4	6
	26	164	8	8

Once again available funds and resources limited the level of effort. Due to funding, the decision was made to control error at the strata level rather than the more detailed pasture level.

2.4.2 Large Scale Photo Acquisition and Interpretation

Based upon the SPM results, large scale photo flight lines were flown as prescribed within the woodland and forest strata. Each large scale photo strip was approximately, .45 km by 2 km and contained 15 stereo pairs of 35 mm 1:1000 scale color photographs.

2.4.2.1 Woodlands

A total of 45 flight lines were flown in the woodland type. Each flight line consisted of 15 stereo pairs. Each pair was interpreted for species composition data. Within the area of stereo overlap each pair was interpreted for species and ground cover types. Heights and foliar densities for each species were recorded.

2.4.2.2 Forests

A total of 46 flight lines were flown in the forest type. Each flight line consisted of 15 stereo pairs. Species composition information was recorded for each pair. All ground cover types and species found within the area of stereo overlap were recorded. Heights and foliar densities were also recorded.

2.4.3 Ground Data Collection

2.4.3.1 Woodlands and Forests

The methodology utilized for ground data collection was to construct two transects each 23 meters in length on the stereo overlap section of each stereo pair covering the ground plot. Individual trees to be measured were pin picked and numbered. Information on tree diameter (ground and stump height for woodland and breast height for forest), height, crown diameter, number of stems, growth and age was collected. As much as possible these same parameters were photo interpreted for the photo plots.

2.4.3.2 Rangelands

Large scale photos were used in the rangeland plots only for the purpose of assisting in locating the plot in the field. Plot

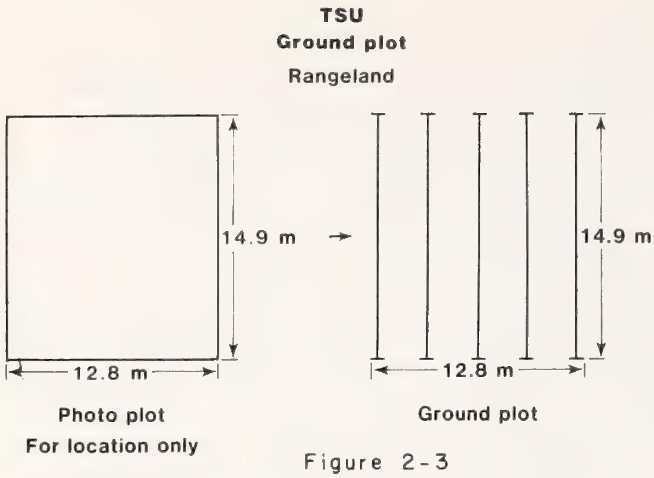

Figure 2-3

locations were defined as the center (pin-picked) of the stereo overlap section of a stereo pair. The location was used as the center of a 13 meter by 15 meter plot. The basic plot consisted of a 200 point grid on 5 lines with a spacing of 38 centimeters along a line and a distance of 3.2 meters between lines. The 200 points were used to characterize species. A systematic set of 20 subplots were used to acquire shrub and weight characterization measurements. Figure 2-3 illustrates the range ground plot configuration.

2.4.4 Tabular Inventory Data

Information produced in this aspect of the project was primarily tabular in nature. Volume estimates by stand for ponderosa pine were developed and volume estimates by allotment for juniper and for pinyon were developed. Rangeland data were categorized by both allotment and pasture, although error was controlled for all data at the strata level. The entire data set for forests, woodlands, and rangelands reposes in a digital data base consisting of Landsat classification results, digital terrain data (elevation, slope, and aspect), photo interpretation results, ground data collection results, and digitized ownership boundaries.

3.0 Output Products

The output product from this type of analysis is a digital data base. This data base contains a variety of inter-related data sets all registered to a common geographic mapping base. Information may be extracted from the geographic data base by coordinates at any scale or in any form practicable. Any combination of data base parameters may be viewed and retained in hard copy form. The low cost of data manipulation and flexibility of the data base allows rapid and frequent revision of any product desired.

Any information that can be described in terms of the mapping base can be entered into the data set. For this particular project, sources of water and road network were both examples of ancillary data sets used. Figure 3-1 is an example of an 8 class land cover map produced from the project data base.

This particular product is simply one way of expressing, in a visible format, information which is contained in the data base. Figure 3-2 illustrates the data which is tabulated on each cover class shown.

Summary Class: 5 **Computer Classes:** 3, 6, 9, 18, 29, 31, 32, 43, 44, 59, 71, 74, 81
Cover Type: Mohave desert shrub
Area: Acres 408,031
Hectares 165,131
% Project Area in Class 17

ELEVATION: 800 ft. - 3,400 ft.
(244 m - 1,036 m)

SLOPE:

Slope	Area (Acres)	% of Class
<5%	219,292	54
6 - 10%	61,302	15
11 - 20%	45,023	11
21 - 50%	45,240	11
>50%	37,174	9

ASPECT:

Aspect	Area (Acres)	% of Class	Aspect	Area (Acres)	% of Class
W	59,080	14	E	52,151	13
NW	51,482	13	SE	47,472	12
N	42,465	10	S	65,835	16
NE	28,631	7	SW	60,915	15

COVER TYPE DESCRIPTION BASED ON PHOTO DATA

Total Photo Plots 1,570

Deciduous woodland		Mohave desert shrub		Great Basin desert shrub		Natural features		Water	
Salt cedar	<1%	Mesquite-acacia	<1%	Blackbrush	<1%	Natural features	<1%	Water	<1%
Salt cedar-shrub	2%	Tall rabbitbrush	<1%	Blackbrush-other desert shrub	<1%				
		Creosote	42%	Snakeweed	<1%				
		Bursage	21%						
		Mixed desert shrub	31%						
Total	2%		96%		1%		<1%		<1%

Figure 3-2

Figure 3-3 is an example of the use of the data base system to ascertain areas of potential grazing suitability.

Table 3-1 is an example of rangeland inventory data which is contained in the data base.

4.0 Cost Analysis

Very detailed information was maintained on the cost of accomplishing this project. A cost analysis revealed that recurring costs - that is, those costs which would be encountered in doing a project of similar scope in another area were on the order of $0.15 per hectare for developing land cover information. In order to produce detailed inventory information on forests, woodlands, and rangelands the costs were $0.37 per hectare. Finally the cost to produce a basic map overlay once the data base was established was $0.002 per hectare. All costs quoted are in terms of 1981 U.S. dollars.

LANDSAT VEGETATION CLASSIFICATION

ARIZONA STRIP DISTRICT, ARIZONA
SOURCE DATA AUGUST 26, 1977
SCENE I.D. 2947-17074
MAPPING UNIT 10 ACRES (4 HECTARES)

"SUMMARY CLASS"		VEGETATION DESCRIPTION
	1	CROPLAND AND PASTURE (1.1)
	2	CONIFEROUS FOREST (2.1)
	3	EVERGREEN WOODLAND (3.1)
	4	DECIDUOUS WOODLAND (3.2)
	5	MOHAVE DESERT SHRUB (4.1)
	6	GREAT BASIN DESERT SHRUB (4.2)
	7	MOUNTAIN SHRUB (4.3)
	8	PLAINS GRASSLAND (5.1)

NUMBERS IN PARENTHESIS REFERENCE HIERARCHICAL NUMBER SYSTEM OF VEGETATION CLASSIFICATION FRAMEWORK

WILDLAND VEGETATION RESOURCE INVENTORY SYSTEM
NASA/BLM ASVT PHASE II
ANALYSIS COMPLETED MAY, 1979
BY U.S. GEOLOGICAL SURVEY, EROS DATA CENTER

Figure 3-1

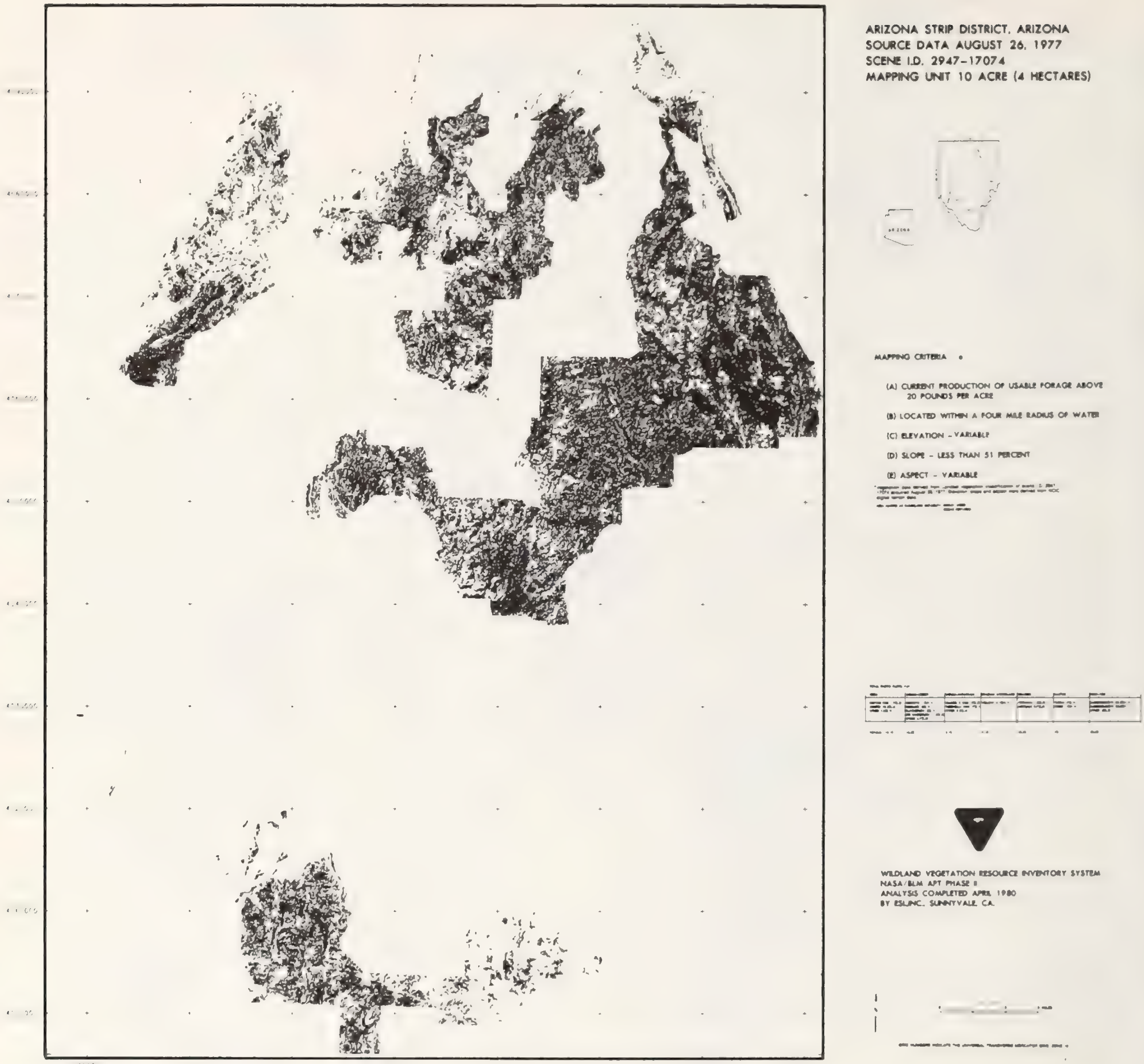

Table 3-1
Pasture Inventory Data

Mainstreet Allotment Pasture	Area (Hectares)	Forage per Unit Area (KG/Hectare)
Cecil	1,585	22.4
Round Pond	1,326	24.9
Square Pond	2,934	22.1
Anthony's Higley	4,017	22.6
Calving	360	23.5
Temple Trail	2,152	20.7
Salaratus	1,776	21.1
Mudhole	2,794	20.6
Twin Tanks	4,806	20.8
Wards	280	20.4
Dutchman	2,807	20.1
Cox-Atkin	6,707	20.1
Englestead	5,854	22.9
Little Joe	5,874	21.0
Bishop and Burr	789	19.3

5.0 Conclusions

This project clearly and unequivocably showed that Landsat could be used for an accurate and economic sampling frame for inventories. It further demonstrated that the resulting geographic digital data base from such a project could be utilized for a variety of management actions. Finally the project demonstrated that inventories conducted using Landsat could be achieved over large land areas at extremely reasonable cost ratios.

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RESUMEN

Este trabajo describe un programa que utiliza los datos Landsat y datos auxiliares para obtener información de inventario de recursos naturales para un clima árido. El área bajo estudio está localizada en la parte noroeste del estado de Arizona y se conoce comúnmente como "Arizona Strip". Esta área está separada del resto del estado de Arizona por el Gran Cañón del Colorado, y está bordeada al Oeste y al Norte por los estados de Nevada y Utah respectivamente. El área es típica del desierto, y contiene una variedad de tipos de vegetación desde gobernadora (creosote), "blackbrush", orégano gigante (big sagebrush) a elevaciones bajas, hasta pinos Piñón y Ponderosa a elevaciones más altas. El área se utiliza mayormente para el pastoreo de ganado doméstico, y es además un habitat para burros salvajes y otros animales de caza tales como el venado. También existen en esta área rodales comerciales madereros, y bosques. El manejo activo del área se lleva a cabo para varios usos tales como: recreación, pastoreo, caza y otros.

Tales usos requieren información de inventario para el buen manejo del área. Este trabajo describe cómo la data Landsat y la data auxiliar se utilizaron para obtener información de inventario de los recursos naturales de esa región. En este trabajo se enfatizan los requisitos para inventario; un trabajo adicional describirá la metodología utilizada. Se discuten los requisitos de inventario, y se describen varios productos para satisfacer esos requisitos. Se demuestra que este enfoque es aplicable a otras áreas de ambiente similar. Se discute el costo por unidad de área, y se cita el beneficio económico obtenido al estudiar grandes áreas dentro de la misma estrata ambiental.

Use of Digital Landsat Data for Integrated Survey[1]

Charles F. Hutchinson[2]

Abstract.-- Techniques of integrated survey are efficient but suffer from a seeming lack of objectivity and consistency; various approaches are examined and their difficulties explained. A test of digital classification of Landsat data for identifying integrated land units was inconclusive. The validity of comparing a Landsat classification against a map is questioned.

INTRODUCTION

Inventories of land attributes (e.g., soil, vegetation and hydrology) can be conducted independently. However, efficient integrated methods of land inventory have been developed within the last forty years which treat land as a complex of all physical elements. This concept of the land complex parallels the classical geographic concept of "landscape".

The task of the surveyor in mapping integrated units is to identify those units of land in which all physical properties are felt to be relatively uniform. However, even in single attribute survey there is often disagreement on how to recognize and define units. Further, after units are defined, there is often confusion as to how they might best be grouped or classified. If there are problems of consensus on techniques for mapping individual resources, there is little hope that criteria could be devised for defining and recognizing integrated units. For this reason, integrated survey has come under criticism for its lack of objectivity.

As in most other systems of natural resource survey, the integrated method relies heavily on the use of aerial photography. It is assumed that significant differences in a single attribute will be accompanied by differences in other attributes, the cumulative effect of which may be detected on aerial photography. Put simply, different integrated units of land are expected to look different from one another. However, the reliance on differences determined by subjective interpretation of photographs has caused problems in repeatability of results. Consequently, the prospect of the availability of digital air-borne scanner data has held hope for increased objectivity.

Landsat satellites record images digitally. Elements of the picture (pixels) cover an area equal to 60m by 80m (approximately 1 acre) on the ground. The response recorded in any particular band represents an area-weighted brightness measure of all surfaces that occur within that pixel. This response is an integration of the responses of all terrain attributes. Due to the integration of the signal that is recorded, it is often difficult to extract the response of individual features.

The purpose of this paper is to evaluate the use of the integrated Landsat response for recognizing integrated units of terrain in a consistent and objective fashion. In the performance of this evaluation, a set of related topics were also examined, including: the logic of classification; the techniques of integrated survey; methods for digital classification of Landsat data; and the difficulties of determining accuracy.

[1] Paper presented at the Arid Land Resource Inventories: Developing Cost-Efficient Methods Workshop, November 30-December 6, 1980, La Paz, Mexico.

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History and Criticism

The method discussed here shares much with other systems of survey, but has a coherent history and a distinctive method (see Christian and Stewart, 1968; Mabbutt, 1968; Mitchell, 1973; Bailey et al., 1978; Ackerson and Fish, 1980). Credit for the development of the integrated survey is generally given to the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO) (Mitchell, 1973). They first developed a comprehensive classification system and used it operationally (Christian and Stewart, 1953). With this system, large areas could be rapidly and inexpensively surveyed for agricultural potential using aerial photography. The units recognized were defined as follows, in order of increasing generalization (Christian and Stewart, 1968, p. 247-248):

1. Site: "A site is a part of the land surface which is, for practical purposes, uniform throughout its extent in landform, soil and vegetation. A small amount of variability occurs within a site, but it is such low order that, at the levels of the survey being made, the variation falls within the units of classification used in each discipline."

2. Land unit. "The land unit is usually a group of related sites which has a particular landform within the land system and wherever it occurs again would have the same association of sites."

3. Land system. "Land units are geomorphologically and geographically associated to form patterns which recur in the landscape. The boundary of the patterns generally conincides with that of some discernible geological or geomorphogenetic feature or process. Within the pattern it is the same land units which recur. Where a different assemblage of land units begins, it is a different land system."

Although the Australians were first to use an integrated scheme operationally, the system does not represent a new perspective in land classification. It was the practical implementation of a line of thinking that had been evolving for some time. Displayed chronologically in Table 1 are examples of integrated techniques that include some of the earliest regionalizations (Herbertson, 1905) and more recent systems suggested by the U.S. Forest Service (Bailey, 1976).

Mabbutt (1968) presented an excellent discussion of the evolution of integrated systems of land classification. He divided the different schemes into three broad categories based on the techniques employed in classification: genetic, landscape and parametric.

Early "genetic" classification of areas into "natural regions," following in the wake of successes in the biological and geological sciences, sought to establish suitable genetic criteria for classifying large areas. A genetic approach to the classification of land appears rational. However, as Linton (1951) points out, the method places severe bounds on the allowable detail in classification because of inherent logical constraints. The primary constraint is that different genetic factors operate at different levels in the hierarchy of the classification scheme, but they do not operate equally in different areas. Therefore, while lithology may be the most important consideration in one area for defining first order units, soil drainage may be of equal importance at the first order in another. As a result, the early genetic classifications tended to be small scale, extremely general and of little practical value.

The "landscape" approach appeared as a response to the genetic systems. The first comprehensive landscape system was proposed by Unstead (1933). Unstead borrowed the concept of a homogeneous "site" from Bourne (1931) and incorporated it into a hierarchical structure. The system he proposed was one built upon "synthetic" units that took into account the total nature of the landscape.

Landscape approaches use the landform as a "first among equals" in the list of attributes that are considered in defining units. However, precisely how "other" factors are to be used in concert with landform is never made clear. The general lack of guidelines and the flexibility of those that exist leaves the system open to question concerning its precision and objectivity. However, according to Mabbutt (p. 17):

> "There is a saving grace in this flexibility from two points of view: first, it accomodates the complexity and the gradational properties of land and secondly, it admits that land unit divisions are, after all, subjective rather than absolute."

The parametric method was proposed to reduce the subjectivity of the landscape approach. Parametric methods are used to more precisely define land units through the use of quantitative techniques and reduce ambiguity in the definition and recognition of units. Of course, subjectivity still exists in parametric systems in the arbitrary selection and application of criteria, but the quantification of those criteria enhances consistency.

Parametric systems are best suited for use in small areas because variance increases with area. To accomodate this variance it is necessary to increase the number and range of the par-

Table 1. A comparison of some land classification systems.

Author	Units of Homogeneity			Units of Pattern	Units of Genetic Significance				
Herbertson (1905)									NATURAL REGION Climatic zone, based on broad vegetation formation
Bowman (1911)						SUB-REGION Dissimilarities within province	PROVINCE Region of broadly similar topography; based on structure, process and stage of evolution		
Fenneman (1916)						SECTION Area sharing a common erosional history	PROVINCE Region of similar form resulting from certain process	DIVISION Region resulting from a great constructional event	
Bourne (1931)			SITE Area of similar local climate, physiography, geology and soil	REGION Association of sites					
Wooldridge (1932)	FACET Differing shapes of flats and slopes		FLATS AND SLOPES Ultimate units of relief; offer limited variety of habitats						
Unstead (1933)			FEATURE Component of stow	STOW Area of relative homogeneity; composed of a set of features	TRACT Clearly a geographic unit; variable criteria	SUBREGION Collection of broadly similar tracts; common relief or geologic structure	MINOR REGION Elevational zone; may be based on vegetation		MAJOR REGION Climatic zone; vegetation formation
Christian and Stewart (CSIRO, 1968; developed, 1946)	SITE Uniform in form, soil and vegetation		LAND UNIT Group of related sites with same landform	LAND SYSTEM Geomorphically and geographically associated pattern of units					
Linton (1951)			SITE Area homogeneous in structure, and evolutionary history (from Bourne)	STOW A set of related sites (from Unstead)	TRACT Unit with a common structure and evolutionary history (from Unstead)	SECTION Region with a unity of erosional history (from Fenneman)	PROVINCE Major relief type; common structural evolution (from Fenneman)	DIVISION Subdivision of a continent; result of a great geologic event (from Fenneman)	
Vinogradov *et al.* (Soviet, 1962)	SITE One portion of an elevational cross section		FACIES Area of homogeneous site and habitat conditions (1:10,000)	UROCHISHCHA Association of facies related by landform (1:100,000)	MESTNOST A set of genetically and geochemically related *urochishcha* (1:1,000,000)	LANDSCAPE A region (<1:1,000,000)			
Brink *et al.* (MEXE, 1966)	LAND ELEMENT Uniform in soil, form and vegetation		LAND FACET Group of elements, reasonably homogeneous and fairly distinct (1:10,000 to 1:1,000,000)	LAND SYSTEM Recurrent pattern of genetically linked facets (1:250,000 to 1:1,000,000)	LAND REGION Lithologic unit or association with common geomorphic evolution (1:1,000,000 to 1:5,000,000)		LAND PROVINCE Common surface forms expressive of 2nd order structure or large lithologic association (1:5,000,000 to 1:15,000,000)	LAND DIVISION Gross form expressive of continental structure (1:15,000,000)	LAND ZONE Major climatic region
Lacate *et al.* (Canadian, 1969)			LAND TYPE Fairly homogeneous combination of soils (series) and chronosequence of vegetation (1:10,000 to 1:60,000)	LAND SYSTEM Recurring pattern of landform, soil and vegetation (1:125,000 to 1:250,000)	LAND DISTRICT Major physiographic and/or geologic pattern (1:500,000 to 1:1,000,000)	LAND REGION Distinctive regional climate as expressed by vegetation (<1:1,000,000)			
Zonneveld (ITC - UNESCO, 1972)	SITE A single taxonomic unit for at least one land attribute		LAND FACET Pattern of sites related in properties of at least one attribute, commonly landform	LAND SYSTEM Combination of land facets forming a convenient mapping unit at reconnaissance scale	MAIN LANDSCAPE Combination of land systems				
Bailey (U.S. Forest Service, 1976)	SITE Single soil type or phase and single habitat	LANDTYPE PHASE Group of sites having same soil series and related habitats	LANDTYPE Group of phases with similar soil series or families with similar plant communities (Daubenmire, 1968)	LANDTYPE ASSOCIATION Group of landtypes with recurring patterns of landforms, lithology, soils and vegetation association	DISTRICT Part of a section having uniform geomorphology (Hammond's land surface region, 1964)	SECTION Climatic climax vegetation (Kuchler's vegetation types, 1964)	PROVINCE Broad vegetation region with same zonal soils	DIVISION Single regional climate at level of Koeppen's types (Trewartha, 1943)	DOMAIN Subcontinental area of related climates

ameters used to define units. As a result, the amount of information required to characterize an area generally becomes unwieldy. Also, many of the subtleties of terrain that are easily incorporated in the landscape system cannot be adequately expressed without a large number of parameters.

Recent Difficulties

Overall, landscape approaches have been most successful; they are widely used outside the United States. However, as these approaches have been applied to larger areas, there has been a perceived need to develop classification criteria prior to survey (a priori). Generally, the criteria that were developed were genetic, or based on the assumed knowledge of landscape origin and the processes involved (see Brink et al., 1966; Lacate, et al., 1969; and Bailey, 1976 in Table 1).

Webster and Beckett (1970), working under grant from the Military Engineering Experiment Establishment (MEXE), spelled out the assumptions upon which a "neo-genetic" system is built (p. 56):

> "It was assumed that wherever similar rocks weathered in environments of similar climate and tectonic and erosional history, similar landscapes would be found. It was thought that the number of different combinations of these would be moderate and that recognition of similar areas should not prove difficult. This would allow very economical use of available information. Wherever in the world it was collected, information could be used to plan operations at any other site on the same facet."

In a major test of the system, Webster and Beckett (1970) attempted to map physiographic units in the hot deserts of the world with the hope of predicting soil characteristics. Although the classification scheme they developed was logically complete, it was found that no reliable predictions of site characteristics could be made in widely separated areas. It was concluded that the evolution of landscapes was not really understood and the remainder of the project was restricted to characterizing land facets within the same locality.

Not all systems have such problems. The MEXE example (after Brink et al., 1966) is a deductive deterministic system. The pre-defined units are assumed to have a common origin. In contrast, the most frequently used systems (Australia, Canadian, Soviet, and ITC) share a strongly inductive method in their lack of higher order units in the hierarchical structure and their loose definition of units at all levels.

Although the Australians have made statements concerning the genetic relationships of units at the land system level, they are expressed in different ways (Christian and Stewart, 1968). No system of classification exists prior to survey, and units are defined as they occur in the course of the survey. Classification takes place as a separate and later step (a posteriori); genetic linkages are established after survey.

The a posteriori approach, characterized by the Australian method, is found to parallel the classical system of taxonomy outlined by Blackwelder (1967). In his scheme the first task of taxonomy is description of individuals (alpha taxonomy). After individuals have been described, a systematic classification can be developed (beta taxonomy). Finally, after gaining an understanding of the arrangement of groups and their significant attributes, genetic relationships may be proposed (gamma taxonomy). Thus, paradoxically, in the system that is most often held up as an example of genetic classification--Linean taxonomy--it is found that theories of genesis are a product of classification rather than a guiding principle.

Problems of Consistency

Most criticism of integrated techniques has been aimed toward the "landscape" methods. As discussed, the units that are used are extremely vague. Bie and Beckett (1973) found extreme variability in the results of four different mappers' interpretations of the same area. Likewise, Story et al. (1976), when comparing the work of three different interpreters in their ability to duplicate detailed survey results by visual interpretation of Landsat imagery, felt that (p. 291),..."the mapping is as much a matter of the worker's arbitrary decisions as of his skill or the clarity of the boundaries."

Because the system is integrated and sensitive to all terrain attributes, the proper use of criteria is not easily spelled out. However, as discussed above, the existence of rigid criteria does not necessarily produce desirable results. Generally, it must be left to the interpreter to make judgement concerning what constitutes a significant change in any one of the attributes with which he is concerned. Thus until now, mapping has tended to be at least as much art as science.

It would appear that the single most troublesome feature of the integrated method of terrain classification is the imprecise way in which units are defined or recognized. Mabbutt (1968) foresaw the digital use of multispectral scanner data in the delineation of integrated terrain units. Since then, preliminary work has been done using digital Landsat data in Australia

(Robinove, 1979). The work that is reported here is a continuation of that effort.

LANDSAT

Characteristics

Imaging Landsat satellites have been orbiting the earth since 1972, providing essentially complete coverage every eighteen days. Images are recorded digitally; observations in four parts of the visible and near-visible spectrum are recorded for each pixel (Table 2). A variety of techniques exist for handling these data in digital form in an objective and consistent fashion.

Table 2.--Description of Landsat data.

Band	Spectral Region	Color	Brightness Levels
4	.5 - .6 μm	green	0 - 127
5	.6 - .7 μm	red	0 - 127
6	.7 - .8 μm	infrared	0 - 127
7	.8 - 1.1 μm	infrared	0 - 63

Considerations

Landsat is a popular data source because of its availability, low cost, repeat coverage, and its digital format. However, even though it has been used digitally for over eight years, it is only now coming into its own as a tool for resource inventory. Several problems have contributed to this.

Most digital Landsat processing techniques have grown out of agricultural applications. The agricultural environment is especially well suited to the use of automated techniques. Boundaries of units (fields) are normally well defined and can be assumed to be essentially homogeneous, at least so far as intended use is concerned. The variation between fields of similar class is relatively small. Further, the approximate number of classes of interest is known from the outset so that an a priori classification system is appropriate. Generally speaking, the performance of most automated techniques in identifying crop types has been good.

When digital techniques have been applied to "natural" environments, they have not always worked well. The variety found in the natural environment causes problems due to the heterogeneity of potential information classes; a single signature cannot possibly define an information class. Normally, it is necessary to have several different sub-classes to accomodate this variance. As a result, the number of classes produced in an analysis of a "natural" scene cannot be estimated accurately (Hoffer, et al., 1974). Boundaries of potential units are imprecise and their identity may not be clear. Thus, it is often inadvisable to begin digital spectral classifications for resource application with a rigid list of desired information classes. Given the rigid institutional constraints under which many inventories are conducted, this is often a distinct handicap.

The characteristics of the Landsat system have also caused difficulties. As indicated above, the area of a pixel is approximately 60 m by 80 m. The spectral information that is recorded for each pixel is an integration of all surfaces within that area. Thus, all landscape elements that show a surface to the satellite contribute to the signature of a particular pixel. This often has been a problem to those interested in mapping a single land attribute, such as surface geology or vegetation (Siegal and Goetz, 1977; Bentley et al., 1976). One solution to the problem of confusion of signatures and overlap between different land attributes is to devise a method whereby the effects of unwanted information are factored out. The alternative that is proposed here is to deal instead with the integration as it exists in the data.

The use of digital techniques of classifying Landsat data to map integrated units appears to be a complementary combination. Digital classification lends objectivity to the definition of integrated terrain units and offers the hope of repeatability. Using Landsat's integrated data to identify integrated land units could avoid the confusion often found in single attribute applications.

DESCRIPTION OF EVALUATION

Study Area

The eastern Mojave Desert was chosen as a test site for several reasons (Figure 1). First, the large and relatively simple patterns of the desert were judged to provide a suitable test environment. Second, the California Desert Plan Staff (DPS) of the Bureau of Land Management (BLM) had completed a comprehensive survey of the area in 1976. Third, the region contains arid types representative of most terrain found in the California desert.

Data and Equipment

All analyses were performed on equipment located at the U.S. Geological Survey Earth Resources Observation Systems (EROS) Data Center in Sioux Falls, South Dakota. All image manipulations, including sampling, cluster analyses,

Figure 1. Location of study area.

maximum-likelihood classification, and geometric image transformation and registration, were performed on an Interactive Digital Image Manipulation System (IDIMS) produced by Electromagnetic Spectrum Laboratories (ESL). All programs, subroutines, and functions that were used are capabilities of this commercially available system.

A single scene acquired on June 23, 1974 (Landsat ID 1700-17422) was used in the analysis. A smaller area within the scene measuring 1530 pixels by 1104 pixels (92 by 88 km) was selected for study, centered on the settlement of Kelso, California. (Figure 2).

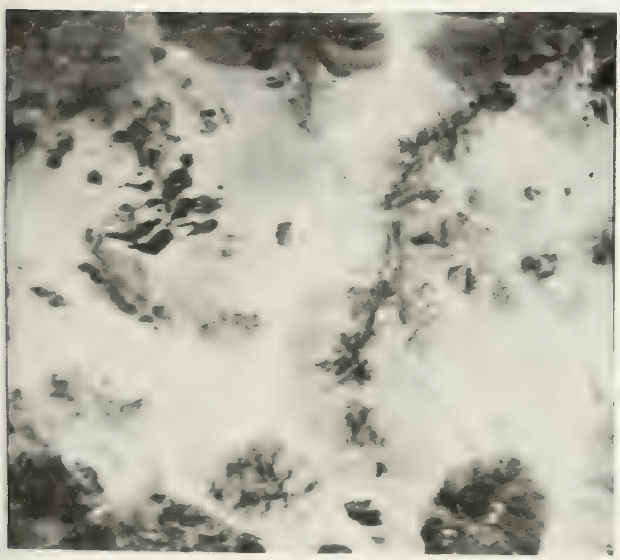

Figure 2. Kelso subscene of Landsat scene 1700-17422, June 29, 1974.

Classification Techniques

Three different approaches to digital Landsat classification were used: supervised, unsupervised, and modified clustering. Descriptions of these approaches can be found elsewhere (see, for example, Swain and Davis, 1978). The discussion of classification that follows focuses on their application to the problem that has been outlined.

The supervised approach was judged to be the least flexible and most difficult to duplicate of the three. At the outset of a supervised classification the analyst must have an idea of the number of classes he will identify. However, as mentioned above, this is difficult to anticipate in a natural resource inventory. In addition, the results of a supervised classification depend heavily on the skill of the analyst in selecting training sets. Thus, the results are difficult is not impossible to duplicate.

The modified clustering approach is superior to the supervised in that it can better accomodate unexpected variety. However, it is still dependent on the skill of the analyst in selecting cluster blocks. Thus, given the goals of achieving objectivity and consistency, of the three approaches that were examined, only the unsupervised was evaluated fully. By relying on well-defined and easily duplicated methods it was felt that the unsupervised approach offered the best prospects.

A 2% random sample was drawn from the entire subscene. Cluster analysis was performed on the sample and 50 distinct spectral classes were produced. (IDIMS default values for minimum number of cluster members (30), minimum distance to means between clusters (3.2), and maximum standard deviation within clusters (2.0) were used). No evaluation of the clusters was possible because the sample was random: all clusters were allowed to stand and the entire subscene was classified into the 50 classes, using the maximum likelihood classifier. The relatively large number of classes was used to accomodate the expected variability of land classes.

Following classification, spectral classes were displayed in pairs or groups on the color video display. In this way groups of spectral classes were identified which were felt to represent land classes. The process resembled the assembling of a mosaic in which the number, shape and class of tesserae were known, but their colors were not. In the end, there were 9 groupings of spectral classes (Figure 3 and Table 3).

By relying on the analyst in fitting together groups of spectral classes a great deal of subjectivity exists even in the unsupervised approaches to classification. However, in the unsupervised approach that subjectivity is introduced in the later phases of the classification process rather than the beginning. Thus, it may be that errors in judgement can be more quickly and easily corrected.

Table 3. Legend for Unsupervised Classification.

Color	Landform	Soil	Vegetation
Sand	Sand dunes and hummocks	Deep quartz sand	Widely scattered grasses (*Hilaria rigida* and *Panicum urvilleanum*) and occasional shrubs (*Larrea tridentata*)
Tan	Sand plains and low gradient alluvial fan (often with veneer of eolian sand), < 3% slope, no stream dissection	Deep fine sands to loamy sands, often saline in lower-lying areas (Torripsamments)	Poor cover (average < 10% of Creosote bush scrub (*Larrea tridentata* and *Ambrosia dumosa*) or Alkali Sink scrub (*Atriplex polycarpa*)
Yellow	Low gradient alluvial fan, generally < 3% slope; no stream dissection	Soils of variable depth, loamy sands with gravelly surface textures; irregular occurrence of calcic horizon (Torriorthents/[illegible])	Typical Creosote bush scrub (average < 15% cover) with occasional cholla (*Opuntia spp*)
Orange	Slightly dissected alluvial fan, gradients < 8%, stream entrenchment < 3m	Deep sandy loams to loamy sands; cobbly surface, cambic horizons not uncommon (Torriorthents/Camborthids)	Creosote bush scrub with cholla and occasional Mojave Yucca (*Yucca schidigera*), average < 10% cover
Red	Dissected alluvial fan, gradients to 15%, stream dissection to 10m +	Moderately deep loamy sands to loams; cobbly surface; subsurface duripans or argillic horizons common (Torriorthents/Durorthids/Haplargids)	Relatively poor spiny Creosote bush scrub with cholla and frequent Mojave Yucca; averages to 15% cover

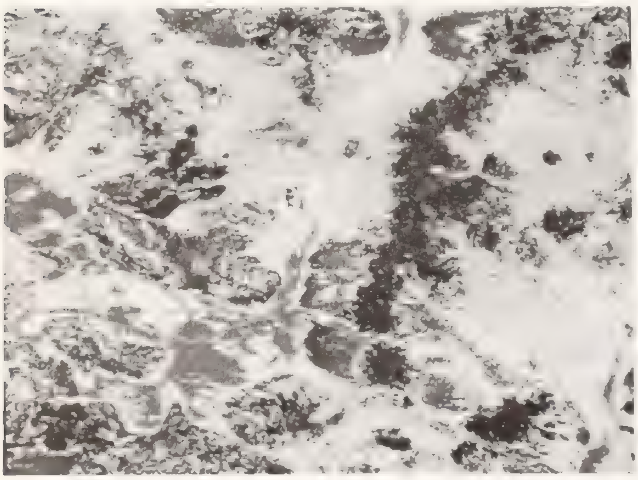

Figure 3. Unsupervised classification of Kelso subscene.

Several problems in the classification were apparent prior to detailed evaluation. First, the large number of clusters did not result in a larger number of usable spectral classes. Rather than capturing the subtle variation of land classes, many spectral classes tended to represent boundaries or random variation within classes. Second, the random sampling strategy while consistent, had an inherent high frequency bias: features of limited extent were either missed in sampling or discarded in clustering. In that many important desert land resources, such as water features, are of limited extent but of considerable importance, this was judged a severe handicap.

Finally, aside from the expected confusion between some classes such as shadows and dark surfaces, in all classifications there was little sensitivity to large differences in vegetative cover. Often, it was impossible to distinguish between surfaces with 10% cover and surfaces with 25% cover. Others have noted this dif-

Table 3. (cont.)

Color	Landform	Soil	Vegetation
Light green	Alluvial fan, undissected to slightly dissected, gradients < 8%; elevation > 1000m	Deep sandy loams to loams; gravelly surface textures; relatively [illegible]	Relatively diverse Creosote bush scrub to Joshua tree woodland [illegible] *Ephedra spp.* and Mojave Yucca, average [illegible] cover
Dark green	Mountains and hills, elevations generally > 1400m, various slopes	Generally shallow soils with loamy textures; relatively low [illegible] color values	Pinyon-Juniper woodland [illegible] cover [illegible]
Brown	Mountains and hills, elevations generally < 1400m, slopes > 15%	Shallow soils with loamy sand to sandy loam textures (Torriorthents)	Relatively rich spiny scrub [illegible] cover averages < 15%
Black	Basalt/Metamorphic outcrops/deep shadow		

ficulty (Colwell, 1974; Bentley, et al., 1976; Pearson, et al., 1976; and Siegel and Goetz, 1977). These experiences suggest a minimum vegetative cover of 30% to be critical in distinguishing vegetation types using brightness values from 4 bands. However, more recent work in the California desert using 7/5 band ratios appears to have avoided this problem (Bryant, et al., 1979).

Evaluation

Control Data

Between 1975 and 1977 the BLM DPS conducted an intensive resource inventory of the eastern Majave region. Included in the inventory were relatively detailed surveys of vegetation, soil, and landform. These were the data against which the classification was compared.

Sampling

A 300 point random sample, stratified by spectral class, was drawn from the classified subscene. The number of samples allocated to each class was proportional to their area. A minimum of 15 samples per class was used.

A sample grid and random number table were used to select points. A selected cell was used as a sample point only if it fell in a relatively homogeneous area of the classified subscene. This insured that the class identity of the point was unambiguous. Fifteen attributes of soil, vegetation, and landform were recorded for each point.

Tests

The purpose of the test was to determine if there was a positive relationship between individual spectral classes and some set of attributes. In addition, the relationship between landform and attributes was examined in a test of landscape integration. However, classes and attributes are "nominal" data; they have no value associated with them other than their name. The

tests that are commonly used with nominal data are chi-square tests of association or related measures.

Initial calculations of the chi-square statistic showed unreasonably high degrees of association. This resulted from low expected frequencies in the contingency table resulting from the relatively small sample.

The Cramer's V statistic was also calculated to determine the strength of the association between the classification and the set of land attributes. In contrast to chi-square, Cramer's V showed no statistically acceptable association between the classification and any attribute (Figure 4).

Discussion

The null hypothesis, or the notion that the results were anything other than random, cannot be rejected. From this several different conclusions might be drawn.

First, it could be concluded that integrated units of desert terrain do not exist. The wide use of the integrated approach argues against this. Further, the raw frequency data of the sample show definite trends of association.

If the first conclusion is not accepted, an alternative conclusion is that these units cannot be recognized in a digital classification of Landsat data. In a strict sense, this may be

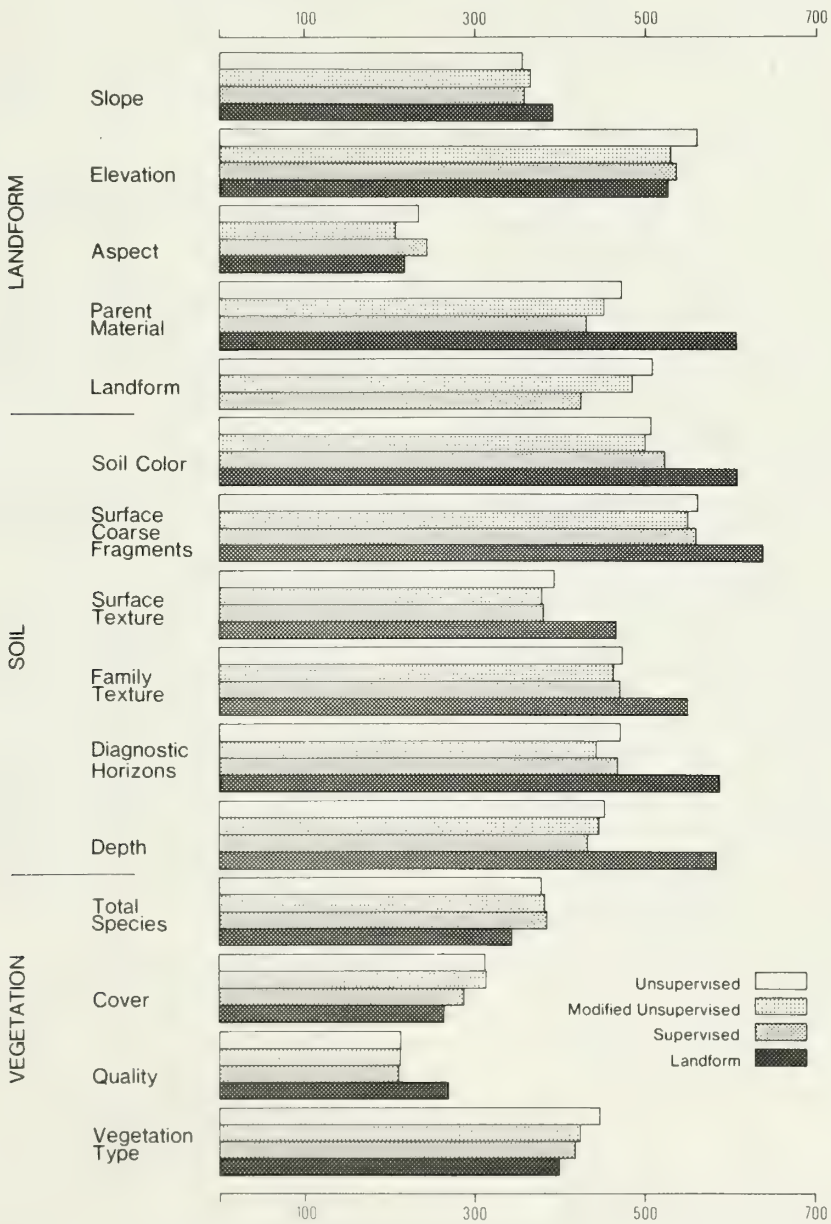

Figure 4.--Strength of association between classification and land attributes (Cramer's V).

true. However, the trends of the frequency data do not support this conclusion entirely. When examined in detail, misclassifications are consistent (e.g., confusion of shadow and basalt) and conceivably could be corrected through stratification or the addition of other information. If nothing else, the units are derived from the classification make a reasonable "first cut".

If neither conclusion is acceptable, the third is that the tests are invalid. This may be true in at least two senses. The sample size may be too small to draw any valid conclusions. However, there are more fundamental problems arising from the comparison of nominal data sets.

The control data (maps) that were used are themselves classifications. Yet, in mapping, there is a lack of agreement on the identify of the object or individual that are classified. Individual surveyors see the same landscape in different ways, as shown by Bie and Beckett (1973) in their comparison of the work performed by several experienced soil mappers. Thus, when two classifications of the same object are compared, coincidence of the two is unlikely. When the comparison is between one classification that subsumes many others and a set of other maps from a variety of sources, results must be expected to be correspondingly disappointing.

Problems of comparison of classification may also be laid to the nature of classification themselves. Classifications are generalizations in which detail is sacrificed for ease of human comprehension (Cline, 1949). The subtle gradations of character between and within classes disappears when objects are classified. The single, best example of the problems of generalization in classification is encountered when an attempt is made to establish precise site characteristics through the use of a choroplethic map. All points within a polygon are assumed to have the same characteristics, even though it is known that the qualities portrayed in the map are gradational from one point to another. If an individual point is sampled, there is no way to place it within the class of which it is a member; it may be a marginal member of the group or may characterize the class as a whole, but this cannot be known from the classification. Thus, while the classification being tested may in fact represent as good an ordering of units as the system against which it is compared, there is no way to know their true relationship based on a comparison of individual cases. The only suitable method for evaluating a classification requires field visitation of each sample point. If maps must be used, accuracy expectations should be lowered.

Summary

Examination of the logic of classification showed that for integrated land classification: 1) systems of division are generally unable to produce acceptable results at a useable scale; 2) systems of classification which use criteria developed _a priori_ are prone to difficulty, especially if those criteria are genetic; and 3) the most successful classifications are those that proceed _a posteriori_ and lack elaborate hierarcies.

In this test, the hypothesis that digital Landsat can be used to recognize integrated units of land cannot be accepted or rejected on statistical criteria. However, frequency data show positive trends of association between spectral classes and land attributes.

Results of the test point up the questionable validity in comparing spectral classifications with maps. It is suggested that in further tests of spectral classification, sample points be visited rather than relying on maps for determining site characteristics.

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USO DE DATOS DIGITALES "LANDSAT" PARA ESTUDIOS INTEGRADOS[1]

Charles F. Hutchinson[2]

Abstracto.--Las técnicas empleadas en estudios integrados son eficaces pero parece que no son objectivas y consistentes; se examinan y explican varios métodos y sus dificultades. No se dedujeron conclusiones satisfactorios de un "test" de clasificación digital de datos "Landsat" para la identificación de unidades de terrenos integrados. Se pone en duda la validez de una comparación entre la clasificación "Landsat" y los mapas.

Los inventarios de los atributos del terreno (tierra, vegetación e hidrología) se pueden hacer por separado. No obstante, en los últimos 40 años se han desarrollado eficaces métodos integrados de inventariar tierras que tratan los terrenos como un complejo de todos los elementos físicos. Este concepto de tratar a la tierra como algo complejo es similar al concepto geográfico clásico de "paisaje."

La tarea del diseñador de mapas de unidades integradas es identificar aquellas unidades de terrenos en que todas las propiedades físicas se dan relativamente por igual. Sin embargo, aun en estudios singulares hay desacuerdo sobre cómo reconocer y definir las unidades. Además, una vez definidas las unidades, suele haber confusión sobre qué manera sería la mejor para agruparlas y clasificarlas. Habiendo problemas de consenso sobre las técnicas en catalogar las materias primas individuales, hay menos posibilidades aun de poder fijar criterios para definir e identificar unidades integradas. Por esto, los estudios integrados han sido criticados por su falta de objectividad.

Un estudio detenido de la lógica de clasificación mostró que para la clasificación de terrenos integrados: 1) los sistemas de división son incapaces de producir resultados aceptables y útiles, 2) sistemas de clasificación que usan criterios desarrollados a priori generan dificultades, especialmente si esos criterios son de carácter genético, 3)las clasificaciones válidas son aquellas que progresan a posteriori y que no tienan jerarquías muy elaboradas.

En este "test" la hipótesis que "Landsat" digital se puede usar para reconocer unidades integradas de terrenos no se puede aprobar o rechazar con criterios estadistícos. Sin embargo, hay frecuentes datos que muestran tendencias positivas de asociacion entre tipos espectrales y atributos de tierras.

Los resultados del test cuestionan la validez de comparar clasificaciones espectrales con mapas. Sugerimos que en futures tests de clasificación espectral se escojan lugares para visitar en lugar de depender de mapas para determinar sus características.

[1] Este estudio se presentó en El Taller sobre Inventarios de las Materias Primas en Tierras Aridas: Desarrollo de Metodos Rentables, 30 noviembre-6 diciembre. 1980. La Paz. Mexico.

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DETECTIT:

An Algorithm for Enhancing and Editing Images of Wildlands[1]

Elliot L. Amidon[2]

ABSTRACT.--Aerial photography and satellite pictures are needed for extensive inventories of arid lands. Maps and tabular data can be derived with the help of computers and picture processing techniques. DETECTIT, a computer subprogram, can isolate and label regions in an image. This distinguishing capability is useful when a decision requires the distribution as well as the total area of a land classification.

INTRODUCTION

Arid land resource information can be extracted from satellite and aerial imagery and from maps derived from them. It is desirable to automate the slow and error-prone process of interpretation as much as possible. Various conceptually simple algorithms can aid spatial analysis. One such aid, DETECTIT, a computer subprogram, and subject of this paper, detects and counts regions, or in the jargon of pattern recognition, "blobs." The usefulness of such a process is illustrated easily in the binary case of water and its background--land. Assume that each picture element (pixel) is individually classified as water on the basis of its pattern or spectral signature. Total water area would be the product of pixel size (e.g., 1/4 ha) and the number of pixels. The algorithm proposed would yield a higher level of information, namely the size, number, and location of the patches of water.

DETECTIT as a tool for spatial analysis has many uses. Maps can be converted into digital form by hand coding grid cells or densitometric scanning of binary images. The code of one class of interest, such as "ponderosa pine with manzanita understory" can be processed with all other categories considered as background. A frequency distribution of pine-manzanita by any size class useful to management can be produced readily. Erroneous small areas in source maps can be detected and removed. Fragments may not be errors but may result from the operation of overlaying two or more maps. The slivers remaining from the superpositioning that exceeds a preset acreage threshold can be discarded to reduce distracting detail.

The basic capability of separating regions can be incorporated into computer systems to aid pattern recognition or to answer complex spatial questions. The distribution of the chaparral type by slope class is an indication of fire hazard. Another example is a visibility analysis for a wild or scenic river. One large-scale visibility analysis required joining blocks of thousands of elevation points encountered in the upper Missouri river drainage (Araki 1979). On arid lands, existing algorithms, such as VIEWIT (Amidon and Elsner 1968, Travis et al. 1975), have been used to delineate highly flammable vegetation types visible from a firetower.

RELATED LITERATURE

Literature on remote sensing contains related work in the general area of pattern recognition. More specifically, the processing of digital LANDSAT data requires reclassification of small regions on digital thematic maps (Davis and Peet 1976). Another approach to the simplification and enhancement of images has been applied to forest stand mapping (Kan and Lo 1975). Both forest canopy

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and field crop infections generate image patterns that can be detected and measured by automated techniques (Waller and Jackson 1971).

Various approaches to the digital classification and grouping of pixels have been assembled and described in a major reference (Rosenfeld and Kak 1976). Major related topics, in addition to component labeling and counting, are border following, perimeter measurement, and line thinning. Methods differ markedly depending on whether a picture is scanned with one sweep or not (Selkow 1972). Most digital procedures assume use of a sequential computing mode. An unusual parallel processing algorithm counts objects by use of a shrinking procedure (Levialdi 1972). Various studies have outlined several region counting methods, but the details of implementing computer algorithms are lacking.

METHODS

When discussing methods, it is convenient to introduce a few terms and to recognize that more extensive and rigorous explanations are available elsewhere (Duda and Hart 1973).

In the programming of a digital computer to separate two-dimensional connected objects, one observes geometric properties of patches such as convexity, concavity, connectivity, and others. One need not be concerned with the properties of continuous figures because a computer "sees" these objects as cellular rather than continuous images. Each cell has a marker that shows the figure's projection into that cell. The cells are considered rectangles and by an arbitrary rule considered entirely occupied, or not. Cell size in relation to the figure determines the accuracy of representation of the original outline.

A set of pixels are connected if every pixel has at least one neighbor in the same set. In a uniform grid the connection may be "4-way", with common cell sides, horizontally or vertically, or connected at vertices. Diagonal or vertex connection is visualized easily as the corner adjacency of the black squares on a chessboard, with red as the background. Lumping edge-connected and vertex-connected pixels together constitutes 8-connected.

A region consists of one or more pixels, each with an identical label. Regions and their background must be oppositely connected to avoid ambiguity. Consider the consequence of using 4-connected for the objects and 8-connected for the background. The result is that the object below has a hole with a 4-connected background, and does not have a hole with a 8-connected background.

```
 1
1 1
 1
```

The algorithim supplied in this paper assumes regions have 4-way connected pixels.

Overview of Region Labeling

The basic problem of region labeling is to tell one blob from another; that is, to assign unique labels to regions. Both blobs and background are transformed into a mosaic of rectangular cells with values zero (background) or 1. The computer reads rows of 0,1's and gives each new region another label. The algorithm proceeds horizontally along data rows in a sequential, systematic manner, and does not know at first that two (or more) regions are equivalent. The following example shows that only on the third scan line is enough information available for an algorithm to ascertain that two regions are equivalent. At the question mark there is the dilemma of assigning A or B to the pixel:

```
A A
  A A   B B B
  A A A ?
```

Once the conflict of assigning equivalency is discovered, any one of several ways can resolve it, each with computer memory and computing time tradeoffs. Immediately after the ambiguity one could read the data rows backward to the beginning. Any B-label encountered that was 4-way adjacent to an A-label would be relabeled A. In this manner A would propagate until another conflict arose. The block of rows could be read repeatedly until conflicts ceased and all regions had unique labels. This procedure would trade input/output time for computer memory space.

Another alternative would be to record each conflict and construct a table of equivalents. The input/output time spent changing B to A, only to find out that another conflict again changed the labels, could be saved. After analyzing all conflicts, another pass through the data would assign the unique labels to regions. Input/output time could be saved at the expense of additional computer memory. The amount of storage required depends on the number of conflicts encountered, and this number cannot be anticipated.

Between these two major approaches are an unknown number of alternatives. The algorithm presented is closest to the second, storage-dependent type, in that it accumulates a record of label conflicts for resolution.

A Labeling Algorithm

The process of indentifying regions can be understood easily by observing a few steps taken by the algorithm (fig. 1). The 5 x 7 matrix consists of 4 objects shown as 1's with a background of zeroes. Given 4-way connectivity, it is apparent that two of the objects are isolated pixels (fig. 1A). All rows are examined sequentially and each pixel is considered sequentially also, starting with the first. In the first row, two new regions are encountered (fig. 1B). In the second row, vertical and horizontal adjacency occurs and the additions are labeled accordingly (fig. 1C). A conflict develops in the third row: in an equivalence table, the smaller of the two values is the patch number, unless a smaller number occurs later (fig. 1D). An isolated cell is given the next highest available number, 3, in the fourth row. In the next row, another region is started (fig. 1E). Two more regions are started in the next row, and one pixel already has a neighbor in the previous row (fig. 1F). In the last row, the second isolated pixel is revealed and another labeling conflict develops (fig. 1G). An equivalence table shows the final numbers (1, 3, 4, 5) assigned to the four patches (fig. 1H).

```
10010     10020
11010     11020
01110     01110
10000     30000
00001     00004
10101     0
00111     0
 (A)       (E)

10020     10020
0         11020
0         01110
0         30000
0         00004
0         50604
0         0
 (B)       (F)

10020     10020
11020     11020
0         01110
0         30000
0         00004
0         50604
0         00664
 (C)       (G)

10020     table(1)=1
11020     table(2)=1
01110     table(3)=3
0         table(4)=4
0         table(5)=5
0         table(6)=4
 (D)        (H)
```

Figure 1.--A binary picture is found to contain four regions at the end of one sweep.

This simple example demonstrates several major points. The main requirement has been met; at the end of one sweep through the data matrix, all regions have been assigned unique numbers. The final numbers are not consecutive: two out of six original numbers were dropped. This reduction shows that an unknown amount of storage must be provided for temporary region numbers. Another consideration is that region count depends on the type of connectivity assumed. If 8-way connectivity had been applied the number of regions would have been three. The reason for the reduction is that the first, previously isolated pixel is diagonally adjacent to the first patch.

DISCUSSION

The algorithmn, DETECTIT, solved the region counting problem posed. Every region has an identity, whether isolated or not, and from frequency counts of the pixels, acreage can be derived. In application, however, adaptations will be needed that have not been demonstrated. Data sets that exceed memory storage available will have to be partitioned. The borders between subsets will be treated differently than the edge of the entire picture. A procedure is required to merge borders and process interior ones appropriately.

Data sets will vary widely in terms of the amount of "noise," or fragmentation, that occurs. Pictures with a high proportion of isolated pixels will require far more memory storage than those with large regions of simple outline. In extreme instances, a pre-processing algorithm to remove isolated pixels is recommended. The variation to be expected in practical work suggests that the algorithmn presented is not the last word on the topic. The computer program described in this publication is made available with the understanding that the U.S. Department of Agriculture cannot assure its accuracy, completeness, reliability, or suitability for any other purpose than that reported. The recipient may not assert any proprietary rights thereto nor represent it to anyone other than as a Government-produced computer program. A FORTRAN mainline can provide the 5 x 7 matrix discussed earlier, and call for the subprogram DETECTIT (fig. 2). The subroutine is adaptable to computers with diverse applications. The user provides the calling routine and inserts checks to avoid overflows.

DETECTIT

```
      SUBROUTINE DETECT(APIC,NREG,
     1TABLE,KT,M,N,IP,DEVICE)
      DIMENSION APIC(M,N),NREG(M,N),
     1TABLE(IP)
      INTEGER APIC,TABLE,BIG,DEVICE
```

```
      LIT=0
      BIG=0
      L=0
      DO 10 I=2,M
      DO 10 J=2,N
      IF(L.GE.IP) GO TO 1
      IF(APIC(I,J)) 10,10,11
11    NAA=NREG(I,J-1)
      NBB=NREG(I-1,J)
      IF(NAA.EQ.0) GO TO 7
      NA=TABLE(NAA)
      GO TO 3
7     NA=0
3     IF(NBB.EQ.0) GO TO 9
      NB=TABLE(NBB)
      GO TO 4
9     NB=0
4     CONTINUE
      IF(NA.EQ.0.AND.NB.EQ.0) GOTO 12
      GO TO 13
C     START NEW REGION
12    L=L+1
      TABLE(L)=L
      NREG(I,J)=L
      GO TO 10
C     EITHER NA OR NB CAN BE ZERO BUT
C        NOT BOTH
13    IF(NA.EQ.0) GO TO 14
      IF(NB.EQ.0.OR.NA.EQ.NB) GOTO 15
      GO TO 16
C     NB IS NON-ZERO
14    NREG(I,J)=NB
      GO TO 10
C     THE ONLY NEIGHBOR IS NA OR BOTH
C       NEIGHBORS ARE EQUAL
15    NREG(I,J)=NA
      GO TO 10
C     UNEQUAL NEIGHBORS ARE NON-ZERO AND
C       ARE TO BE MADE EQUIVALENT
16    LIT=MIN0(NA.NB)
      BIG=MAX0(NA,NB)
      DO 20 K=BIG,L
      IF(TABLE(K).EQ.BIG) TABLE(K)=LIT
20    CONTINUE
      NREG(I,J)=LIT
10    CONTINUE
      WRITE(DEVICE,8)((NREG(I,J),
     1J=2,N),I=2,M)
8     FORMAT(1H ,5I3)
      KT=0
      IF(L.EQ.0) GO TO 5
      DO 30 K=1,L
      WRITE(DEVICE,105) (K,TABLE(K),KT)
105   FORMAT(1H ,'K,TABLE(K),KT=',3I3)
      IF(TABLE(K).EQ.K) KT=KT + 1
30    CONTINUE
5     WRITE(DEVICE,6) KT
6     FORMAT(1H ,'NO. OF REGIONS =',I3)
      GO TO 2
1     WRITE(DEVICE,17) IP
17    FORMAT(' QUIT,MAX. REGION COUNT')
2     RETURN
      END
```

Figure 2. A detailed procedure to label regions in a binary picture will function on many computers.

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RESUMEN

Debido al expanso vasto de las tierras aridas, el analista de inventario debe depender de las fotografías aéreas y de la imaginería satélite para la clasificacion inicial de inventario y muestreo

subsiguiente. La interpretación y la manipulación manual de los datos a una forma cartográfica, sin embargo, son prohibitivas en términos de tiempo y costo. Hay un instumento automatizado que puede aislar y clasificar exactamente las regiones en un imagen a un costo menos que la manipulación manual de tales datos. El instrumento, llamado DETECTIT, es un subprograma de computador.

Este papel describe cómo el algoritmo separa y enumera modelos binarios. Como en cualquier análisis de modelo, una vez que cada elemento tipo imagen se clasifique, el próximo paso consiste en agrupar los elementos y determinar su área, perímetro, u otra característica fundamental. El fin de separar una clasificación específica de sus antecedentes supone que la distribución de tamaño - clase es importante. En algunas situaciones, como para fines industriales, el área total de agua en un área es información suficiente. En otras situaciones, como administración de caza, el tamaño y distribución especial de cada cuerpo de agua son esenciales.

Cómo funciona DETECTIT, sus ventajas y desventajas, están descritos detalladamente. Intercambios entre almacenaje y tiempo se puede contar con que ocurran con cada aplicación de computador. La ejecución de DETECTIT puede ser llevado a cabo fácilmente en computadoras de capacidades diversas. Este papel se refiere a los accesos alternativos descritos principalmente en la literatura sobre procesando fotoso percibiendo a distancia. Una comprensión intuitiva de algoritmos es deseable para que las adaptaciones a los problemas de tierras áridas pueden ser facilitadas.

Efficient Arid Land Monitoring Using Landsat Images[1]

Charles J. Robinove[2]

Abstract.--Landsat images of arid regions are particularly applicable to the inventory of land as a resource because each picture element integrates the reflectance of all the terrain features it includes, such as rocks, soils, vegetation, and water. The reflectance data act as a surrogate for integrated land mapping units which are combinations of various geologic materials, soils, and vegetation. These combinations define the use capability of each land mapping unit. Experiments in mapping arid lands for land management have been done in Queensland, Australia, and the Mojave Desert, California. These experiments have shown that integrated land management units for large areas can be efficiently mapped and described by using digital classification of Landsat images followed by field sampling and integrated terrain unit description.

Once land management units have been satisfactorily mapped and described, monitoring of changes in their status and capability can also be done with digital Landsat images where repetitive data are available. A low-cost efficient system has been developed to create albedo images from Landsat images, measure the increase or decrease of albedo between two dates for all picture elements, and field check those areas where change has occurred. Since most changes that will decrease the productivity of arid land will also increase its albedo, the method offers an effective way to identify only those areas of significant change, update the resource inventories only where change has occurred, and guide field observations and sampling in cost-effective manner.

INTRODUCTION

Landsat images can be used to monitor arid regions in an effective and efficient manner. Their use has many advantages over conventional methods that greatly outweigh their inherent limitations. Advantages of using Landsat data are that (1) each image covers a large area, about 34,000 km^2 in a single view; (2) the image is acquired under nearly the same solar illumination conditions throughout the scene; and (3) the same scene may be reacquired at regular intervals.

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A limitation of Landsat images is that they are surrogate data; that is, they present spatial relations and spectral reflectance properties rather than the identification of specific surficial materials, vegetation type, and geologic condition or measurement if biomass per unit area.

The basic key to successful use of Landsat images in increasing the efficiency and effectiveness of arid land monitoring is to use the advantages of the Landsat images to the fullest and to use other methods, such as finer resolution aerial photography and ground sampling, to offset the limitations of the Landsat data and to calibrate the images quantitatively, wherever possible.

INVENTORY

Monitoring landscape changes of arid regions must be preceded by an inventory of the features that exist and the phenomena that

act on those features. Inventory is a time-consuming and expensive task and often can be hampered by an inability to collect enough vital data within the period of investigation. More serious, however, is the problem of sampling data. Inventories of arid regions, whether they be of the geology, soils, vegetation, or other features, always require that the sampling (which may or may not be statistically sound) be done in such a manner that the inventory units can subsequently be described and mapped. The process of mapping is classically the process of drawing map boundaries around units that are homogeneous or acceptably heterogeneous for the purpose of the map (Varnes, 1974). This process may be done by field mapping, such as geologic mapping, in which the stratigraphic section is described and the stratigraphic units are mapped from their exposures. Map boundaries of the rock units are interpolated between exposures because in many areas exposures are few and far between.

Aerial photographs and Landsat images, however, provide a view of all of the terrain. They provide, in essence, a 100-percent sample from which the terrain can be described, interpreted, and mapped. The advantages that Landsat images have over aerial photographs are their uniform recording of the reflectance of very large areas, their digital multispectral character, and therefore their quantitative format. The essential question when Landsat images are to be used for inventory and mapping is: is the Landsat image data a meaningful surrogate for the desired terrain data?

Many reports have been published on the use of Landsat data for mapping many types of features, such as crops, geology, rangeland vegetation, and water, with varying degrees of accuracy. Reasons why the accuracy is usually not as high as is desired are usually ascribed to the statistical methods or algorithms used in computer processing of the Landsat digital data. Much of the discrepancy, however, can be ascribed (although not in a quantitative sense) to the land-classification scheme used rather than to statistical means of categorizing the Landsat data.

For example, in an arid or semiarid region where vegetation density is low, the spectral reflectance measured by the Landsat scanner is basically that of the soil and rock, modified only slightly by the reflectance of the vegetation. One should not expect to be able to map with high precision the vegetation alone. In a sense, this is a classic signal-to-noise problem. If vegetation reflectance is the desired "signal," then the "noise" of the soil reflectance is so large that the total signal is highly imprecise. To overcome this difficulty, one should not attempt different types of computer processing, but should consider the land classification being used. If the problem is one of creating a land inventory for the purpose of arid land management, then perhaps a vegetation map alone is not the answer, but an integrated map is.

Integrated mapping, pioneered in Australia and used in many other countries, is a method whereby the land is classified and mapped into units that include geomorphic features, vegetation, and soils rather than units which consist only of a single feature. It is further assumed that each piece of land is unique and that its integrated character can be described and differentiated from adjacent lands. The basic category in the integrated mapping approach is the "land system" described by Christian and Stewart (1968) as "an area or group of areas throughout which there is a recurring pattern of topography, soils, and vegetation." Integrated maps, particularly in arid regions, form the basis for broad land-management decisions. Robinove (1979) has shown that such maps can be made by digital classification of Landsat images that compare favorably with those made by conventional interpretation of aerial photographs and ground sampling. The maps produced by Landsat image classification are not identical to published land system maps, but the classes may be described in integrated terms and act as a guide for field checking and ground sampling. Integrated maps made from Landsat images provide a basic inventory of land systems and a description of the terrain and its attributes based largely on multispectral reflectance data used as a surrogate for the actual terrain data.

MONITORING

Given the reliability of a land inventory made by use of Landsat images, the next step is the vital one of updating the inventory at appropriate intervals or of monitoring change in the land and its attributes.

Landsat data may be used to detect and measure the change in albedo of the terrain, pixel by pixel. Description and classification of the changed areas may be done partly by Landsat image analysis and partly by ground checking.

A method for calculating the albedo of each Landsat pixel has been developed by Robinove and others (1980). Landsat images of the same area, taken at two different times, are digitally converted to albedo images in which the digital number for each pixel is the albedo in percent. The images are digitally registered to each other, and the earlier image is subtracted algebraically from the later one, producing an image whose pixel values are the number of percentage points (either plus or minus) that the pixels have changed in the intervening time. Digital density slicing can then be used to produce maps of all pixels whose albedo has increased (or decreased) more than a given number of percentage points. The process can be automated to the point where the analyst selects the significant level of change of albedo to be displayed.

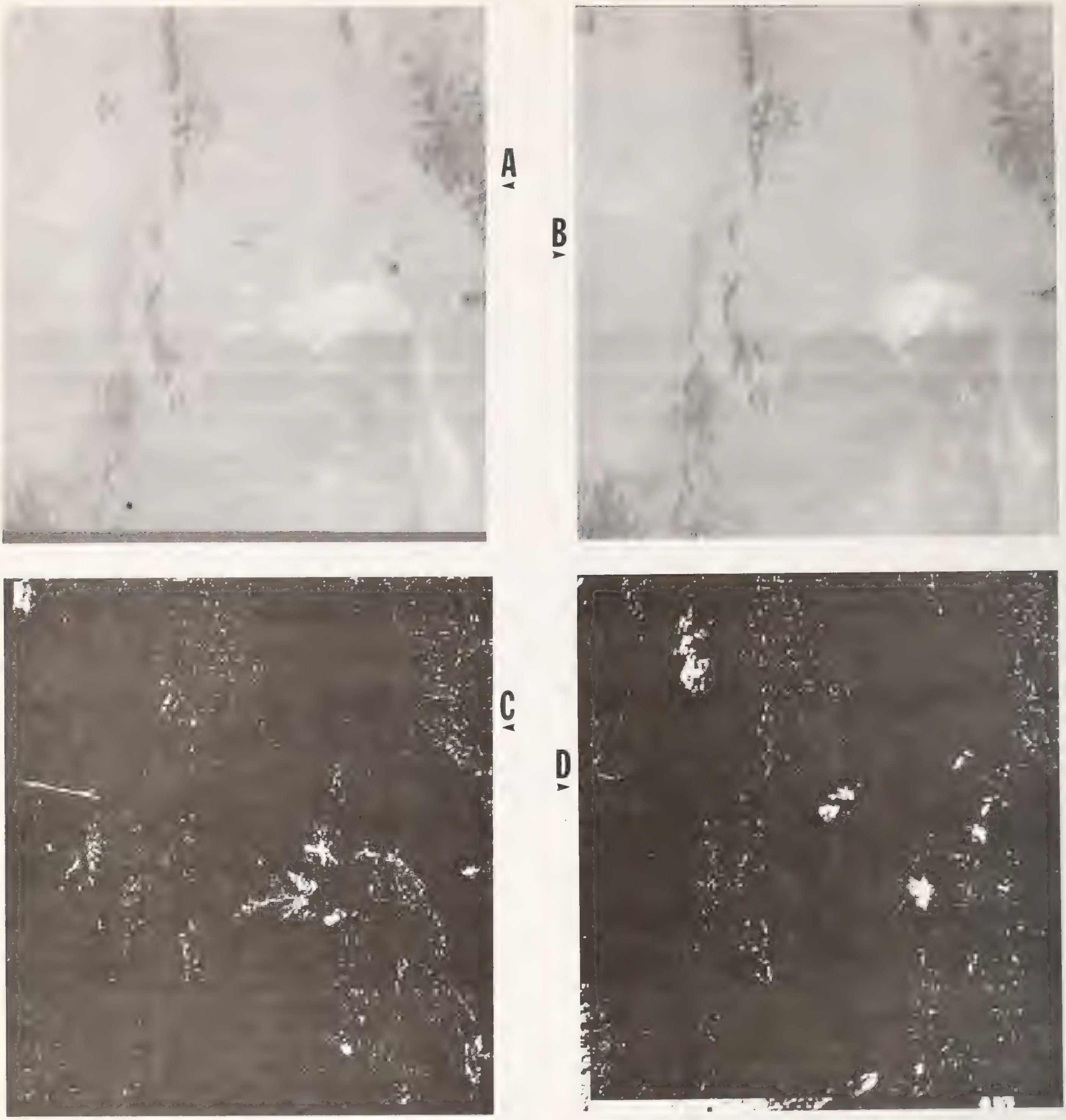

Figure 1.--Albedo images and albedo change maps. A and B are albedo images of an 18 x 18 km area in Pine Valley, Millard County, Utah, made from 512 x 512 pixel subscenes of Landsat images taken on September 3, 1974, and September 25, 1975, respectively. The gray scale is proportional to albedo. Image A is subtracted from image B to produce an albedo difference image (not shown) which is density sliced to produce the albedo change maps C and D. C is a map of those pixels (white) whose albedo has decreased by more than 7 percentage points in the 1-year period. D is a map of those pixels (white) whose albedo has increased by more than 5 percentage points in the 1-year period. The terrain-related albedo decrease patterns in C are generally caused by increased soil moisture and increased growth of annual plants in 1975. The terrain-related albedo increase patterns in D are generally caused by drying of the playa surface (light area near center of A and B).

A change in albedo represents a change in terrain features or their attributes but does not tell exactly what has changed on the ground, or how it has changed. This must be determined in the field. In an arid region, most changes, whether natural or manmade, that tend to lower the biological productivity of the land will increase the albedo, and changes that decrease productivity will increase the albedo. Pixels that have decreased in albedo in terrain-related map patterns may be caused by increased density or vigor of vegetation, by increased soil moisture, or by other factors, either singly or in combination. The cause or causes must be determined on the ground. Figure 1 is a pair of albedo images and a pair of albedo change maps that show the change that has taken place in 1 year in an area in western Utah.

Using Landsat data to prepare albedo change maps of an area does away with the necessity for field mapping for terrain monitoring. Ground crews instead can go directly to areas that have changed significantly to determine the cause. The efficiency of this method of inventorying the land and monitoring its change depends on the use of the cost-effective Landsat digital images. Landsat data are relatively inexpensive per unit ground area, whereas field work is quite expensive per unit area. Utilizing the Landsat data for classification and inventory leads to efficient deployment of ground crews for field sampling and checking.

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RESUMEN

Las imágenes Landsat de tierras áridas son particularmente apropiadas para el inventario de la tierra como recurso, ya que cada elemento de fotografía (pixel) integra la reflectancia de todas las características del terreno que abarca, tales como las rocas, el suelo, la vegetación y el agua. La data de reflectancia puede substituir a las unidades cartográficas de tierra integrada que incluyen material geológico variado, suelos y vegetación. Estas combinaciones determinan la capacidad de uso para cada unidad cartográfica de tierra. En Queensland, Australia y en el Desierto Mojave de California se han llevado a cabo experimentos en cartografía de tierras áridas para el manejo de tierras. Estos experimentos han demostrado que las unidades de manejo de tierra integradas para grandes áreas pueden ser cartografiadas y descritas eficientemente utilizando la clasificación digital para imágenes Landsat seguidas por muestreo de campo y descripción de la unidad de terreno integrado.

Una vez las unidades de manejo de tierras han sido satisfactoriamente cartografiadas y definidas, la observación de los cambios en su estado y capacidad puede también llevarse a cabo en las imágenes digitales Landsat donde la data repetitiva está disponible. Se ha desarrollado un sistema eficiente a bajo costo para crear imágenes albedo de las imágenes Landsat, para predecir el aumento o disminución del albedo entre dos fechas distintas para cada elemento de fotografía y para inspeccionar en el terreno aquellas áreas donde haya habido cambios. Ya que la mayor parte de los cambios que causan una disminución en la productividad de tierras áridas también causarán aumento del albedo, este método ofrece un medio efectivo para identificar sólo aquellas áreas con cambios significativos, para poner al día los inventarios de recursos sólo donde haya habido cambios, y para orientar las investigaciones en el campo en una forma más eficaz.

Resources Inventory Techniques Used in the California Desert Conservation Area[1]

Ronald G. McLeod[2]

Hyrum B. Johnson[3]

A variety of conventional and remotely sensed data for the 25 million acre California Desert Conservation Area (CDCA) have been integrated and analyzed to estimate range carrying capacity. Multispectral classification was performed on a digital mosaic of ten Landsat frames. Multispectral classes were correlated with low level aerial photography, quantified and aggregated by grazing allotment, land ownership, and slope.

BACKGROUND

The issues which land management planners must address arise from the fundamental conflicts which occur with an increasingly expanding and mobile population and finite natural resources. The intricacy and complexities of human activities often place severe pressures on the desert environment and its ecosystems. Historically, the preservation and improvement of the natural environment has taken a back seat to progress and the development of natural resources. State and Federal legislatures are responding to the pressures put on the environment by enacting laws in which environmental values and conditions are appraised and preserved. The appraisal of environmental conditions requires inventory; and a good inventory is absolutely basic to subsequent planning.

The Bureau of Land Management (BLM) in the State of California has been mandated by Congress to prepare and implement a comprehensive, long-range multiple use management plan for the 25 million acre California Desert Conservation Area (CDCA) shown in figure 1 and provide in the plan protection and appropriate use for the 12.1 million acres of BLM administered public lands in the CDCA.[4] The Act requires that the plan take into account the principles of multiple use and sustained yield in providing resource use and developement, while assuring the maintenance of environmental quality. Twelve plan elements were formulated to prescribe desert-wide management direction for Cultural Resources, Native American Values, Wildlife, Wilderness, Wild Horse and Burros, Recreation, Motorized Vehicle Access, Geology-Energy-Minerals, Energy Production-Utility Corridors, Land Tenure Adjustment, Vegetation, and Livestock Grazing.[5] It is the input to the management direction for the Vegetation and Livestock Grazing elements that is the theme of this paper.

The BLM currently leases 4.5 million acres of the CDCA in 53 grazing allotments for cattle and sheep grazing. Approximately 60,000 sheep (40,000 animal unit months, AUMs) and 10,000 cattle (120,000 AUMs) obtain all or part of their sustenance from the California Desert (fig. 1).[6] Sheep grazing is generally intermittent depending on the locality and type of ranching operation, as well as the pattern of annual rainfall. Proper management

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[1]Paper presented at Arid Lands Resources Inventories Workshop. [La Paz, Mexico, November 30-December 6, 1980]. This paper presents one phase of research conducted at the Jet Propulsion Laboratory, California Institute of Technology under NAS7-100, sponsored by the National Aeronautics and Space Administration.

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[4]Federal Land Policy and Management Act, Section 601, Public Law 94-579, the 94th United States Congress, 1976.

[5]The California Desert Conservation Area Final Environmental Impact Statement and Plan, U.S. Department of Interior, Bureau of Land Management, October 1, 1980.

[6]An AUM is the amount of forage required to sustain one cow, or its equivalent, for one month; 450 kg. air dry weight of forage.

techniques dictate that accurate range carrying capacity estimates be calculated to insure a sustained yield multiple use of the land for grazing. Just as improper range management can lead to reduction of production capacity, improper management may also lead to failure to allocate all lands suitable for grazing, thus wasting usable forage.

Although the BLM leases only 4.5 million acres of the 25 million acres in the CDCA, grazing allotments are distributed throughout the entire region, often including private land parcels. Resource information must be gathered in all parts of the desert in order to properly estimate the production of forage and in turn determine range carrying capacity. Resource information for this sparsely occupied portion of the state is incomplete. Data available for specific areas vary in type and quality, presenting difficulties in obtaining uniform interpretations. Due to time and budget constraints, methods other than conventional mapping and inventorying techniques were needed to obtain much of the required resource data. The feasibility of using multispectral classification of Landsat digital data for the CDCA plan was explored by representatives of the BLM Desert Plan Staff at the EROS Data Center[7] in early 1977. In general, the results were highly favorable and the conceived potential was found to

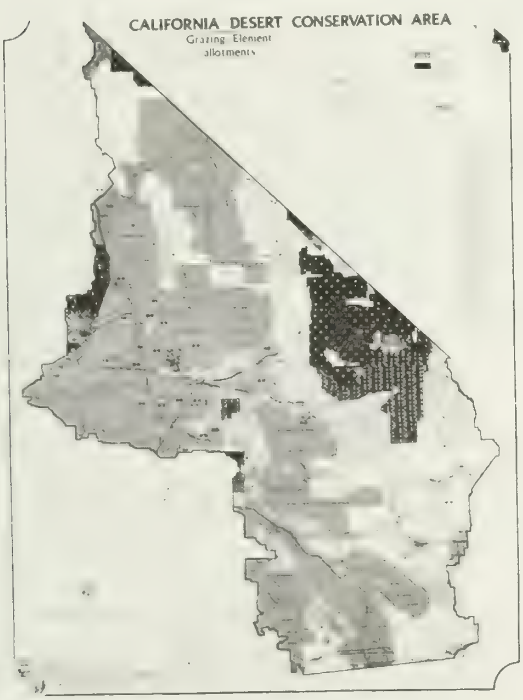

Figure 1.--The California Desert Conservation Area (CDCA) and Grazing Allotments.

[7] Earth Resources Observation System (EROS) at Sioux Falls, South Dakota is a data clearing house for NOAA, USGS, and NASA.

greatly exceed the initial expectations. However, different systems and procedures needed to be implemented if an approach to uniform classification for biomass over the entire region was to be realized.

The BLM was presented with a challenging task: obtain accurate range carrying capacity statistics not only for currently leased grazing allotments but also for all BLM administered lands throughout the CDCA so that decisions in the future could be made as to proper land use and range allocations. Such a problem required the compilation and integration of data from a variety of map and remotely sensed sources as shown in figure 2, a task made difficult by the sheer size of the CDCA.

APPROACH TO THE PROBLEM

The BLM personnel turned to the Jet Propulsion Laboratory's (JPL) Image Processing Laboratory to assist in first preparing a controlled digital mosaic of ten Landsat scenes to cover the entire CDCA prior to digital classification of the spectral data. Considerable work has been done at JPL's Image Processing Laboratory developing geometric rectification and registration algorithms, and more recently, software has been developed for digital image map reprojection and image mosaicking. Image processing support for JPL's planetary program provided the basic software and procedures necessary to achieve digital image mosaicking (Elliott 1976, Johnson 1977).

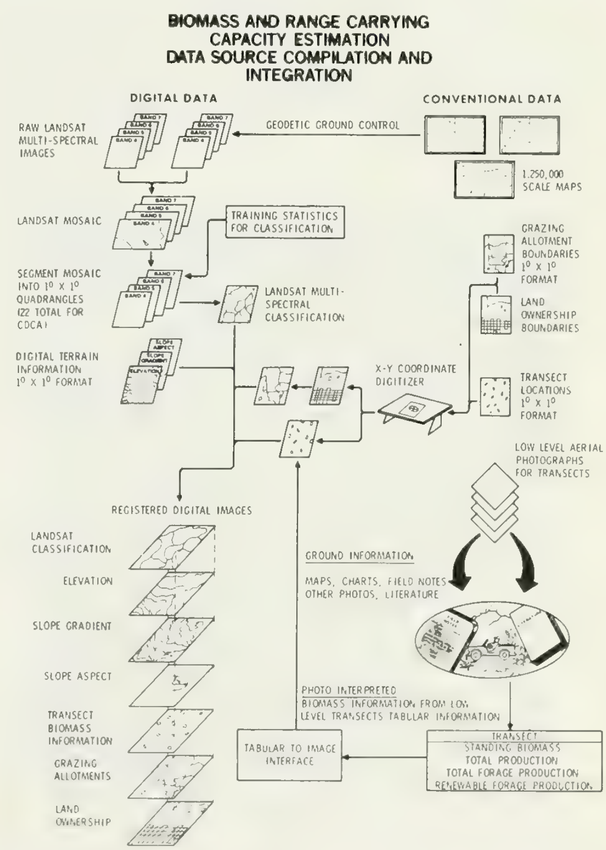

Figure 2.--Biomass and Range Carrying Capacity Estimation. An overview of data type compilation and integration.

The software system used at JPL is VICAR (Video Image Communication and Retrieval) and consists of a language translator that simplifies execution of image processing programs, a series of applications programs that include a broad range of image processing capabilities, and a series of modular subroutines used by applications programmers for data input/output, program parameter input, and other functions (Seidman 1979). The VICAR subset IBIS (Image Based Information System) is discussed in the Data Integration section of the paper. Methods have been developed that not only geometrically correct and register images in the X and Y directions but also correct adjacent frames in the Z domain (i.e., brightness). After corrections are applied to the three axes (X, Y, and Z) of the individual Landsat scenes used, a mosaicking algorithm is employed to construct a single large mosaic image.

Compilation of Data Sources

Landsat Digital Mosaic

The imagery selected for the CDCA regional mosaic were ten Landsat scenes acquired on four sequential cloud free days: August 3, 4, 5, and 6, 1976 (fig. 3). The requirements established by the BLM stated that the data should be cloud free, acquired on consecutive days, imaged during a relatively high sun angle period, and imaged at a time when there was a minimum growth of annuals that could affect signatures. Each image as received from EROS Data Center were logged into the VICAR format for continued processing. Logging consists of unleaving the data into band sequential format and performing nominal corrections for skew, mirror scan velocity profile, and panorama effect and adding a VICAR label to the beginning of each file. After logging, each of the images were 2340 lines by 2430 samples.[8]

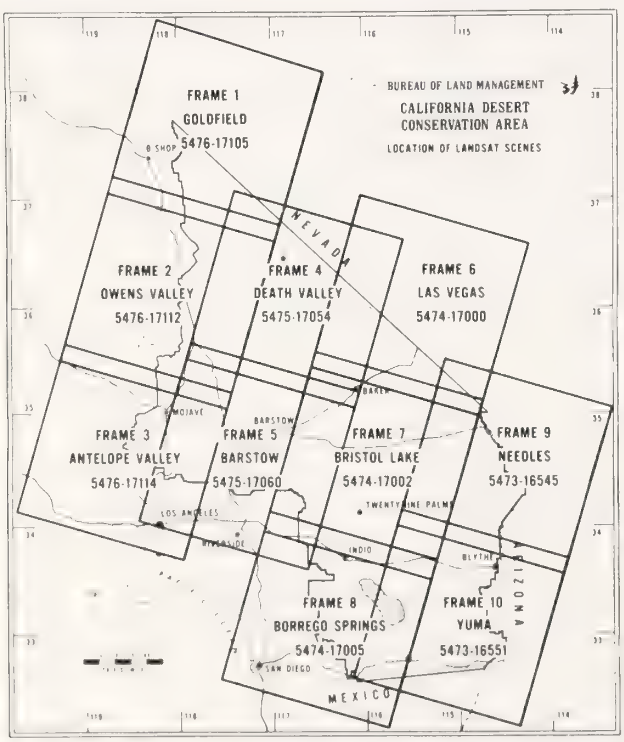

Figure 3.--Location of Landsat scenes used for the CDCA. Images were acquired on August 3,4,5, and 6, 1976.

Planetary mission images and the associated image rectification software differs from the Landsat MSS digital imagery in that the reprojection of vidicon images to specific map projections could be achieved by using the pointing statistics of the spacecraft and then fine tuning the local mis-registration between frames by applying a rubber-sheet geometric distortion correction algorithm a second time (Rofer 1973). In the case of Landsat mosaicking, it was found necessary to incorporate ground control points of known position in the image as well as relative registration points between frames to fine tune any local mis-registration (Zobrist 1978). The reasons for incorporating ground control points are twofold; 1) the multispectral scanner on Landsat is not a framing imaging system, so that continuous changes in pointing perspective geometry make it virtually impossible to reconstruct a perfect orthophoto image from spacecraft calibration data; and 2) the relative position of points on the Earth's surface is precisely known, with the result that geodetic control points must be used as input to geometric correction if the satellite image data is expected to conform to the planimetry of existing maps (Zobrist 1979).

A Lambert Conformal Conic map projection grid for the CDCA region was set up on a programmable calculator to establish the relationship between the image raster, Cartesian space and latitude/longitude. The grid was angled 11° east of north to follow the nominal track of Landsat and reduce the computation cost involved in rotating the large images to north. The selected geodetic control points in each of the 10 Landsat images were mapped to their respective position in the Lambert grid using interpolation between known points. A minimum of nine geodetic control points per frame were used. Converting the image data to a specific map projection allows for easy access to any portion of the finished mosaic. Coordinates of the vertices of an area requiring access are input to the programmable calculator in latitude/longitude in degrees, minutes, seconds and the X,Y (line, sample) positions of the image raster grid are returned. The inverse of this calculation is also available. This capability proved useful for detailed analysis of subareas in the CDCA.

All image data used in the CDCA mosaic were resampled to 80 meters by 80 meters in the X and Y directions to accommodate Landsat sensor and orbital characteristics, local topographic offset affects and to conform to the Lambert Conic grid. Conventional brightness corrections for satellite data are generally in the form of a standard photometric function applied over an entire frame based upon illumination angles and atmospheric interference conditions. Such procedures are adequate when radiometric calibration requiring absolute intensity values are needed. For this application of multispectral classification, a smooth brightness surface was necessary so that abrupt changes in day to day side lap areas were eliminated. A resampling of the brightness or

[8] A line consists of a line of image data and a sample consists of a column of image data.

Z values was performed based upon X,Y coordinate intensity values obtained from the relative registration points used to fine tune the mosaic. Points were interpolated between known points and input to a "rubber sheet" Z correction algorithm.

The final Landsat mosaic shown in figure 4 had the dimensions of 7400 lines by 7500 samples comprising 55.5 million pixels per Landsat band. The large volume of data necessitated that the mosaic, once completed, be broken up into manageable segments to allow efficient computing. A convention of 1° of latitude x 1° of longitude quadrangle segments was adopted, and proved useful in the subsequent registration of ancillary data. There were 22 complete or partial 1° x 1° quadrangles used for the CDCA representing 22 tape files per band dimensioned 1600 lines by 1450 samples (figs. 5 and 6).

Digital Terrain Information

The 1° x 1° quad convention permitted the registration and overlay of the National Cartographic Information Center/Defense Mapping Agency (NCIC/DMA) digital terrain files.[9] Files for the 22 quads used in the CDCA were obtained from NCIC/DMA and first logged into the VICAR format. The elevation data were then converted from halfword to byte to reduce storage and scaled in 8 bits from 0 to 10,000 feet. The data were rotated 90° to orient north at the top (no resampling). Since the latitude/longitude coordinates of the DMA terrain information is known and each point in the Lambert grid is known, the digital data could be mapped and resampled to 80 meter pixels to conform to the Landsat map projected data. After corrections were performed, images depicting measures of slope aspect and slope gradient were calculated. Figures 7, 8, and 9 show the processed digital terrain images.

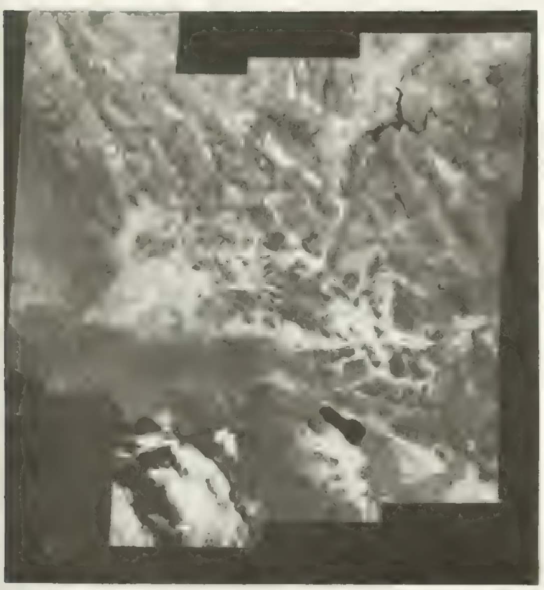

Figure 4.--California Desert digital mosaic. IR1 band, 7400 lines by 7500 samples. Two additional scenes have been added; Upper rt., Lower lft.

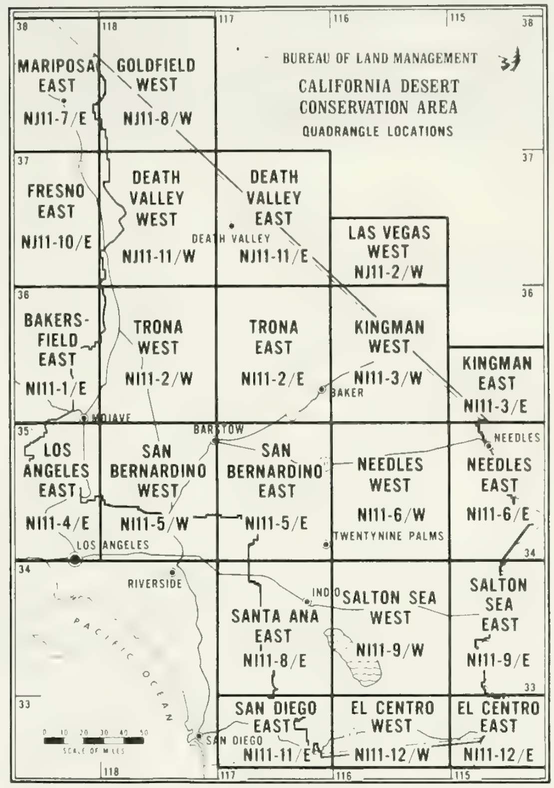

Figure 5.--1° x 1° quadrangle locations in the CDCA.

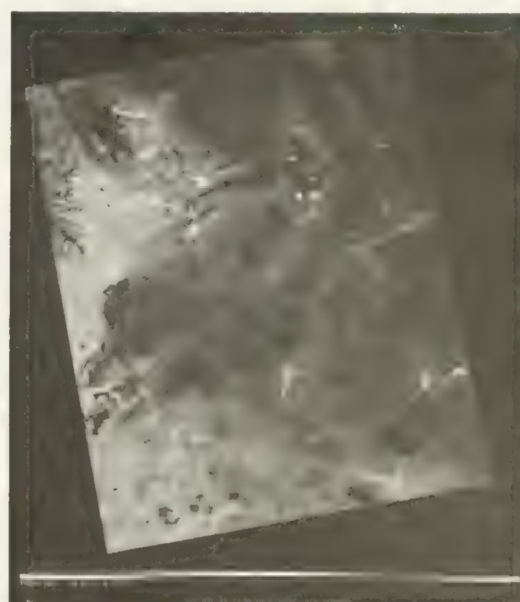

Figure 6.--An example of a quadrangle (Trona West Quad) extracted from the Landsat digital mosaic of the CDCA.

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[9] National Cartographic Information Center. NCIC User Guide, Digital Terrain Tapes., 12pp.

Figures 7 8 9
An example of digital terrain information for the Trona West Quad. Fig. 7.--ELEVATION - The brighter the image, the greater the elevation. Fig. 8.--SLOPE GRADIENT - The brighter the image the steeper the slope. Fig. 9.--SLOPE ASPECT- Brightness increases with azimuth (point of origin at top of image).

Ancillary Ground Information

Ground information played an important role in the biomass estimation process for the CDCA. For instance, many of the initial multispectral classifications would have to be checked and validated with other data. Site specific vegetation data from past surveys, toe point transects, and photographs were used. Additional information as available included 15 minute quadrangle sheets, 1:20,000 - 1:30,000 scale air photos, U2 aircraft photos, and habitat and soils maps.

The 15 minute quadrangle sheets were useful in many ways. First, they allowed checking of geodetic accuracy of the Landsat mosaic data base and allowed quick pin-pointing of areas for close up viewing and investigation. Secondly, the BLM staff was able to verify the registration of the digital terrain elevation data. Thirdly, the maps provided calibration for the slope gradient data derived from the elevation data.

The Desert Plan Staff realized from the begining that most reflectance patterns in a desert environment were primarily the result of surface factors, soil groups, and rock units and that vegetation probably contributed only a minor part. Thus, it would be necessary to include soils maps for understanding plant/soil group associations. Field notes, reports and slides assisted in this process.

Low Level Aerial Transect Selection

The rationale behind including low level aerial transects in the project stems from the necessity of devising an efficient way of establishing the quantitative relationship with the inherently qualitative multispectral classification. Ideally, the procedure to be used in selecting transects for biomass estimation would be to classify the entire CDCA into broad vegetation information classes and then produce a color classification map. Transects could then be located in homogeneous areas within the broad vegetational classes and biomass information could be correlated directly with spectral class. Due primarily to time constraints, many phases of this project were being handled in parallel. While the classification procedures were being developed, it was necessary to initiate a contract to fly low level color aerial photography at 1:2,000 scale with sufficient overlap for stereo viewing. Since the classification was not yet completed, the CDCA color mosaic and BLM resource photography were inspected for candidate locations for transects. Transect selection adherred to the following criteria; that the sites selected represented large areas, that smaller important riparian areas were included, that is was desirable to select transects where field information was already available. Although the process of selection was subjective at times, the main consideration was to select transects representative of the resource types BLM wanted to inventory.

The standard 9" x 9" format was set forth as a requirement and the film used was Kodak SO394 color transparencies. The overflights began in the Fall of 1978, and since 500 were selected over the entire CDCA, the flights were not completed until the early summer of 1979 (fig. 10.). As a consequence, there was a strong potential for having seasonal differences entering in and this would be particularly true in the desert with herbaceous annuals in ephemeral habits. The BLM was concerned with a vegetation inventory and classification based on perennial plants only, mostly shrubs that persist over a period of years.

Cadastral Information

Since the biomass information were later to be aggregated by land ownership and grazing allotment, conventional maps for this information had to be readied for computer input. Maps detailing landownership and grazing allotment boundaries were supplied to JPL by the BLM Desert Plan Staff in the adopted $1^{\circ} \times 1^{\circ}$ quad format. The boundaries were digitized on a coordinate digitizer, converted into images, and registered to each of the 22 quads in the CDCA.

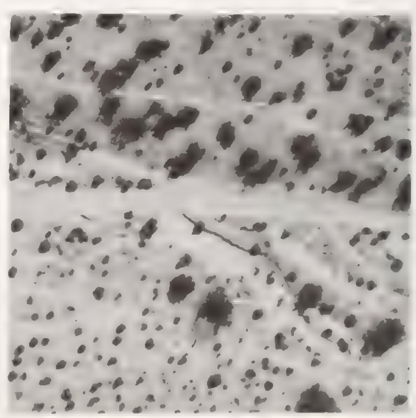


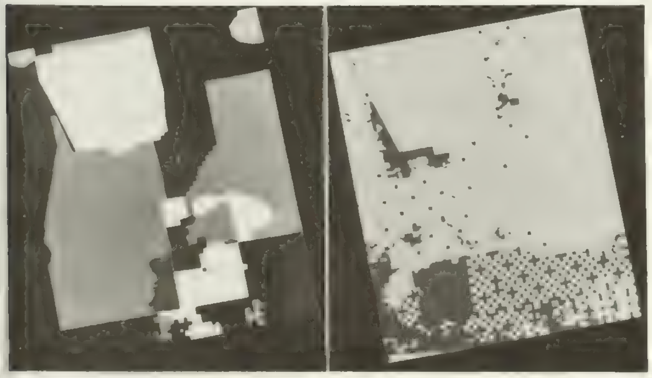
Figure 10.--An example of a low level aerial photo. Transect in the Trona West Quad. Road width is approximately ten feet.

An affine surface fit was used initially to obtain a rough fit, which proved surprisingly good, and later, local variations were corrected with a rubber sheet adjustment. On separate geo-referenced images each grazing allotment was uniquely encoded with a digital value to distinguish one grazing allotment from another. Land ownership was encoded in the same manner with two types: Public and Private (figs. 11 and 12). With the compilation of the data planes completed and registered to common raster grid, analysis, modeling, and aggregation of statistics for biomass and range carrying capacity could begin.

MULTISPECTRAL ANALYSIS AND CLASSIFICATION

The arbitrary nature of essentially all resource classification schemes (ground base and otherwise) was tacitly accepted at the outset. Thus, during the initial phases of establishing the training statistics, little concern was shown for trying to establish spectral clusters that corresponded to known resource types. Typal classifications of natural biological resources (vegetation, habitats, etc.) are most often only intuitive in substance and seldom adequately quantified. This condition has contributed to the difficulties for testing Landsat classifications as observed by Maxwell (1976) working with vegetation production in Colorado, Bentley et. al. (1976) working with vegetation and soils in Arizona and Montana and Hutchinson (1978) striving for an integrated survey method in the Mojave Desert of California. Extreme variability within the ground control classes commonly leads to improper evaluations on how well Landsat can define and discriminate resources.

A basic assumption is made when multispectral classification is used. Spectral reflectance patterns are related in a rational way to resource characteristics and that from this relationship, practical classification schemes can be developed. The first goal in proceeding with the digital multispectral classification then becomes one of establishing a set of spectral cluster statistics that embrace the entire range of spectral reflectance



Figures 11 12

An example of the boundary files for Trona West Quad. Fig 11.--Grazing Allotments displayed in four grey tones. Fig 12.--Land Ownership: Public--light tone, Private--dark tone.

intensities and patterns found in the data set for the CDCA. There is a need for such a fine grained approach. It is critical to derive enough clusters to separate essentially all signatures that might correspond to special purpose resource classes desired for practical applications. The underlying principle of this approach is the opposite of the null hypothesis most commonly used in statistics (type 1 error) but instead relies on minimizing the chances of inadvertently aggregating samples that are different (type 2 error). In terms of the splitter taxonomists, "It is a greater sin to call things that are different the same than to call things that are the same, different." A modified, unsupervised, purely statistical classification was performed to deliver an initial classification of enough discrete classes to separate all resource cover types known to the BLM resource specialists. Even though desert regions are characterized by stable atmospheric conditions for long periods, similar habitats are known to develop changes in plant species composition and abundance over several degrees of latitude and similar changes occur in reflectivity signatures for similar type areas. It was necessary to develop a system of linear transect sampling as a means to assure uniform classification statistics with sufficient discrete classes to include all known resource types. The initial pixel brightness values for all four MSS Landsat bands were extracted in two pixel wide swaths along approximately 3,000 miles of transects delineated by the BLM science team to include all variable types in the landscape (figure 13). This technique is analogous to the Multi-Cluster Blocks approach reported by Fleming and Hoffer (1977) in which the training blocks are selected for their heterogeneity

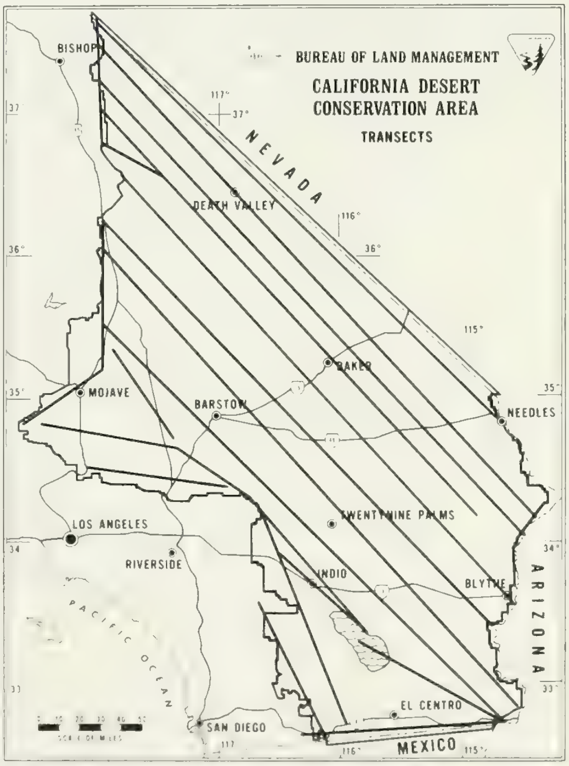


Figure 13.--Sampling transect locations in the CDCA

rather than homogeneity. The transects traversed all types of terrain elevation, slope gradient and aspect, and the various cultivated and populated areas. The transect data were then aggregated into a small (360 samples by 410 lines) image per Landsat band and represented a 0.5% sample of the CDCA. An unsupervised clustering algorithm was employed on the entire small 0.5% sample image resulting in the separation of 1993 initial clusters. Timing for the clustering was approximately 500 cpu minutes on an IBM 360/65.

The unsupervised clustering algorithm which builds up clusters as it passes through the training set was designed to limit the growth of clusters, providing a large set of initial clusters. The initial cluster data set displayed the very broad range of reflectivity values found in the California Deserts. Much of the CDCA is sparsely vegetated, i.e., has less than 10% plant ground cover, and the maximum ground cover rarely exceeds 50% except in cultivated lands which were of little concern to BLM scientists. Riparian areas, with the higher percentage ground cover values, though comparatively small in extent, are of significance in terms of total plant productivity and related range carrying value.

Cluster Reduction

The task of reducing the 1993 clusters to a manageable number became a problem of devising a way to retain significant but small population clusters having a strong vegetative component in their signatures. It is generally known that such clusters should be those with comparatively low reflectance in the visible red band (MSS 5) and high reflectance in the infrared bands (MSS 6 and 7). The goal of obtaining 100 principle clusters from the initial 1993 was established by the JPL and BLM science team for the reason that 100 was a small enough number to efficiently manage and yet retain the diversity of critical elements needed to define the CDCA landscape. In addition, the limit of 100 clusters to the classification algorithm was set to reduce the potential for incurring exhorbenant computing costs. To this end, the 1993 initial clusters were separated into groups based upon the strength of the vegetative component of spectral signatures as indicated if one or both of the infrared bands contained greater reflectance signatures than the visible band. If the visible band was greater than the infrared bands, the vegetative component of the signature was assumed to be nonexistent. If the ratio of MSS band 6 to MSS band 5 was greater than or equal to one, the clusters were determined to represent a plant type signature, and if the ratio was less than one, the clusters represented a non-plant signature. In summation:

$\frac{MSS6}{MSS5} \leq 1$ indicates a plant signature;

$\frac{MSS6}{MSS5} > 1$ indicates a non-plant signature.

The partitioning separated the clusters into 684 vegetation reflecting clusters and 1309 non-vegetation reflecting cluster signatures. Each resultant group was broken down further into two groups to yield four final cluster groups. Of the vegetative reflecting signatures, ($MSS6/MSS5 \leq 1$), these signatures were separated into groups where MSS band 7 was greater than or equal to MSS band 5, representing a very high vegetative component signature containing 363 clusters and where MSS band 7 was less than MSS band 5 such signatures represented a high vegetation signature with a population of 321 clusters. The non- or low vegetation clusters ($MSS6/MSS5 > 1$) were separated into two groups on the basis of whether MSS band 5 brightness was greater than 130 on a pixel brightness scale of 0-255, and yielded 690 clusters. Such signatures represented very bright surface conditions such as playas and sand. The second group was separated as to whether MSS band 5 was less than 130 yielding 619 clusters. These signatures represent dark surface features such as shadows and basalt flows. This strategy resulted in partitioning the 1993 initial clusters into four groups representative of major signature types in the CDCA as shown in table 1.

The reduction of the clusters to approximately 25 clusters within each of the four groups was performed by merging overlapping clusters and deleting the population and associated statistics of clusters where the mean value occurred within the one standard deviation ellipse of a cluster with a larger population. Each of the four groups were merged separately in order to assure that population size and standard deviation would not dominate the merging process. Important low frequency pixel clusters representing strong vegetation signatures were thus retained to be used in the classification process.

Testing the Statistics

Rather than immediately classifying the entire CDCA, (an expensive procedure) the cluster statistics were first tested in sample areas to see if they were appropriate. The one hundred clusters selected for the CDCA were used as input to a hybrid Bayesian/Parallelepiped type classifier and applied to four primary test areas selected in the CDCA (Addington 1975). Each test area was 512 lines by 512 samples comprising over 400,000 acres each. The test areas were selected by the BLM Desert Plan staff for their diversity and representativeness of the varieties of landscapes found throughout the CDCA and on the basis

Table 1.--Relative percent of pixels and clusters in the band ratio-brightness categories from the transect sample training set.

	LANDSAT BAND RATIO-BRIGHTNESS CATEGORIES			
	1	2	3	4
	Band 5 ≤ Band 6	Band 5 ≤ Band 6	Band 5 > Band 6	Band 5 > Band 6
	Band 5 ≤ Band 7	Band 5 > Band 7	Band 5 ≤ 130	Band 5 > 130
Percent of Pixels	6%	12%	52%	30%
Percent of Clusters	18%	16%	35%	31%

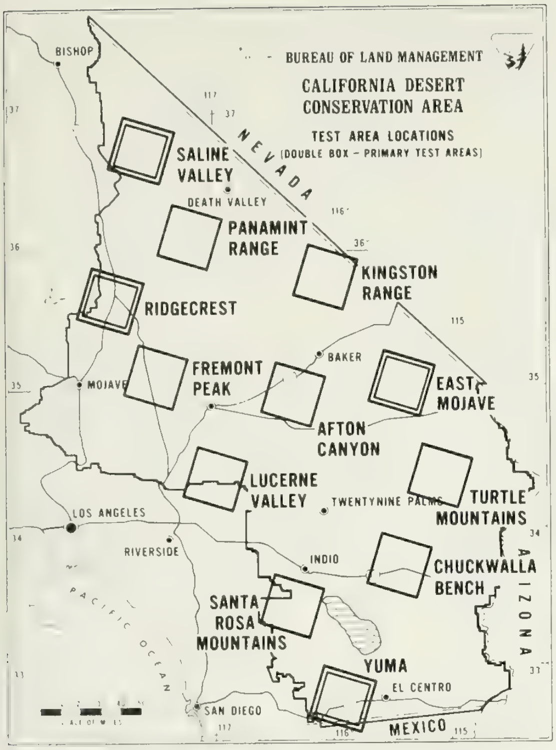


Figure 14.--Location of 512 x 512 pixel test areas.

of available ground information. The spatial distribution of the classes as output from the multispectral classifier were examined for each of the test areas by the BLM staff at JPL on the General Electric Image 100 interactive system. The objective in examining the classes was to determine if:

1) The spectral patterns corresponded to any known distribution peculiar to vegetation groups and plant communities;
2) any inconsistencies in classes were apparent due to the effects of latitude, elevation, slope gradient and slope aspect.

Aided in these determinations with extensive supplemental ground information collected through field surveys and low altitude aerial photography, the BLM staff was able to assign names to the classes and then decide which classes needed merging, expanding, or deletion. Final classification thresholds for the entire CDCA were set at 3 sigma for each cluster for input to the classification algorithm.

The ground information helped spot inconsistencies in classes from test area to test area. It was found, for instance, that with the aid of the registered NCIC/DMA elevation data, many of the inconsistencies in class assignments were resolved. Perennial range type is usually found above 3500 feet in the CDCA while ephemeral range type is generally below 3500 feet. In addition, changes in stratification based on elevation for communities with similar reflectance characteristics often occurred between those test areas in the high desert to the north and in low desert areas to the south.

The 100 class maps for each of the test areas were of such fine detail as to be cumbersome. Classes of like signatures and pattern distribution as determined by the BLM staff were merged, and with the aid of the elevation data to resolve inconsistencies, were collapsed into 28 final vegetation information classes. Each test area was collapsed independently to give a "best fit" for its representative part of the desert. Eight secondary test areas (512 lines by 512 samples) were examined to fine tune this procedure and to insure consistency throughout the entire CDCA. Once the BLM staff was satisfied with class assignments to vegetation types, the respective maps were generated for each of the 22 1° x 1° quads for the CDCA. As a result of the first four test areas and second eight test area experiments, the existence of a systematic drift in signature characteristics from north to south and from east to west was shown. The quads were assigned to each of four quad groups for class reduction to 28 classes.

The quad groupings as shown in figure 15 represent the four major regions of the CDCA as defined by the BLM desert Plan Staff.

Group 1 North Mojave
Group 2 East Mojave/Colorado
Group 3 Yuha
Group 4 West Mojave

Each of the four groups were stratified independently in order to tailor the spectral classes to the region. An example of an inconsistency was apparent in the Imperial Valley shown in Group 3. Pinyon-Juniper signatures, characteristic of the nearby Santa Rosa Mountains, were appearing in the agricultural lands of the valley. An elevation stratification was used to delete any pinyon-juniper signatures

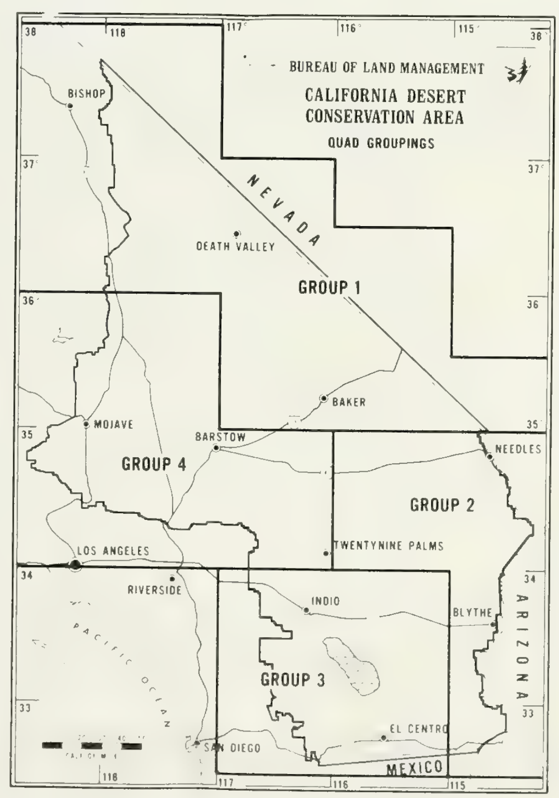


Figure 15.--Quad groupings used in stratifying multispectral classification.

below 40 feet. The gaps that resulted from this operation were filled with neighboring classes as appropriate.

LOW LEVEL AERIAL TRANSECT ANALYSIS AND INTERPRETATION

Large scale aerial photos were used to estimate the biomass and production of perennial plants for selected transects throughout the desert. The goal in the Production/Biomass estimation of perennial plants was to determine range carrying capacity for livestock in designated allotments. The ephemeral component of forage productions, i.e., winter and summer annuals, cannot be estimated on a yearly basis due to the extreme variability of moisture and temperature.

In order to arrive at a quantitative interpretation of the Landsat classification for the purpose of estimating range carrying capacity, it was necessary to extract several types of botanical data from the photo transects. These data included:

1. Species composition--a list of species that were present in the transect;
2. The amount of each species present in terms of percent ground cover;
3. The height of the species present;
4. Volume and inferred density of the species present, derived from the cover and height.

It was important to insure the accuracy of species identification in order to relate Production to Biomass. Extensive use was made of field information regarding what plants were present for transects that had been visited. Height was determined from stereo viewing, but was usually done in a relative sense rather than absolute sense owing to some variability in the scale of the transects. By using well known plants as indicators, the height could be estimated rather closely.

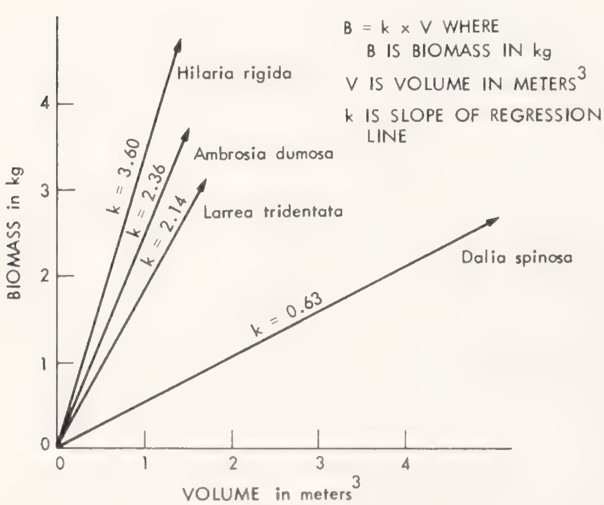


Figure 16.--An example of volume to weight (biomass) relationships for four indicator species. (Storey 1969; Wallace 1972; Garcia-Moya 1970)

With the initial extraction of this data from the transects, it was possible to obtain a value of Standing Biomass in kilograms per hectares (kg/ha). Biomass was determined for the transects through volume measurements related to volume density equations obtained for a spectrum of indicator species (figure 16). However, the biomass values by themselves are not directly useable for determining carrying capacity for livestock. Considerations for both production and palatability to livestock are also important. The task then became one of determining the relationships among biomass, production and palatability.

In the early 1970's, the International Biological Program, Desert Biome portion exerted considerable effort in making measurements of various types on desert plants. Some of the research reported on the relationship between biomass and production for various species. Biomass and production are considered to be positively correlated as a function of woodiness (figure 17). With the production to biomass ratios established for species within the transects a value of Total Production in kg/ha could be ascribed. This value is an estimate of new growth for a year. Taking into account livestock grazing preferences and consulting palatability tables, the production for plant species grazed by livestock was estimated in kg/ha and this value reflected Total Forage Production. After deciding which species were forage producers, proper use factors were assigned each species. The proper use factor, when included, defines the amount of forage that can be consumed by livestock and yet preserve plant production in a sustained yield basis. Palatability and proper use tables have historically been developed over the years by the BLM, particularly, the Riverside District office, Las Vegas District office and the Kingman Arizona District office. The proper use factor for species was multiplied by the Total Forage Production for species to obtain values of Renewable Forage Production.

DATA INTEGRATION

Once the CDCA had been classified into broad vegetation information classes, the task remained to assign biomass/production values to each class

Figure 17.--An example of Production to Biomass (P/B) relationship used in determining Total Production levels of sample transects.

in a region. A technique of back-classification was used to do this. The positions of the transects were plotted on stable base enlargements of each of the 1° x 1° quads used and were digitized. Locating the coordinates was aided with 1/20,000 to 1/30,000 color and black and white aerial resource photography available from the BLM files. After digitizing, locational accuracy was verified on a CRT and supplemented with pixel by pixel listings for selected transects. This was necessary due to the small size of the transects; approximately 40 Landsat pixels. Each transect was then uniquely encoded to identify one from the other and overlaid on the 28 class map. Class values for each transect were tallied and stored in a tabularly formatted IBIS file. An important tool in the data integration phase was the IBIS (Image Based Information System) software package, a subset of VICAR. IBIS is the tabular to image, and image to tabular link in which disparate data types may be compared (Zobrist January 15, 1978). This procedure was repeated for all quads with transects and the output files concatenated to produce a final working file with vegetation information class counts for all transects.

The optimal situation in assigning biomass values to the vegetation information classes would be to have the transects contain homogeneous information, i.e., all the same class per transect. With such a configuration, the interpreted biomass value could be correlated directly with the class residing in the transect. However, in the CDCA case, many of the transects were hetereogeneous, posing some basic difficulties in the back-classification methodology. Utilizing the flexible capabilities of the VICAR/IBIS software, biomass values for spectral classes were averaged over several transects within groups of 1° x 1° quadrangles and weighted by spectral class frequency.

Quadrangle groups for biomass class assignment differed from the quadrangle groups used in collapsing to 28 vegetation information classes because biomass class assignment groups were based on the quads in which there were interpreted transects. By and large, the two grouping schemes are quite similar. The quads which contained transects and the quad groupings are:

Bakersfield East
Trona West
San Bernardino West } Group 1

Death Valley West
Goldfield West } Group 2

Kingman West — Group 3
Needles East — Group 4
Salton Sea West — Group 5

Biomass would then be tabulated for grazing allotments based upon which quad group each allotment was contained in or adjacent to.

In most cases, if more than one class was present in a transect, it was found that those classes were closely associated in vegetation information and could logically be averaged together. This could be justified based on the continuous nature of vegetation. Transects that could not be logically averaged due to class separability were deleted as were transects with no accompanying biomass values. The total number of transects used after editing was 238. In some cases, the composition of spectral class values for all transects in a quad or quad group did not consist of all 28 possible classes, thus leaving gaps in the biomass value assignment. Those were classes that had a very low population and were not captured in the transect sampling strategy. This proved insignificant as those non-sampled classes generally comprised less than one percent of each allotment. This procedure was repeated for Total Production, Total Forage Production, and Renewable Forage Production. Initial tabular reports were generated for BLM Desert Plan Staff inspection and approval.

DATA AGGREGATION

Once biomass values had been assigned to the 28 vegetation information classes for the CDCA, the spectral class map was considered a biomass map. What remained was to tabulate biomass by the grazing allotments leased by the BLM. In addition, it was necessary to obtain biomass values by land ownership (Public and Private) as well as slope gradient. Such information required the intersection of four data sets resulting in 12,768 possible entries. There were two entries for land ownership, three for slope gradient, 28 for the spectral biomass classes, and 76 for grazing allotments. Although there are only 53 allotments, additional areas such as military reservations and bases, national monuments, state parks, and Indian reservations were included. The slope gradient image derived from the DMA terrain data was found difficult to use unless broken into three categories. The categories selected by the BLM staff were 0-25%, 26-50%, and greater than 50% slope. These corresponded to the traditional slope classification used in range suitability determination. Allocations can be made for livestock if the land under consideration has a 0-25% slope as determined by the digital terrain slope gradient information. The 0-25% category embraces essentially all the terrain accessible to livestock. Land with greater than 25% slope was allocated solely to wildlife.

Overlays for the four data sets were performed on each of the 22 1° x 1° quadrangles used in the CDCA to obtain information listing spectral class (biomass) by 1° x 1° quadrangle for grazing allotments, land ownerhsip, and slope category. This resulted in 22 intermediate disk files (one for each quad) which were concatenated into one master file to simplify the data management. Since many grazing allotments were not contained within the confines of a single quad it was necessary to tabulate accross quad borders, an operation made possible when the data is tabularly formatted.

Since the assumption of signature extension in such a wide and diverse area such as the CDCA is not valid, it was necessary to tabulate biomass

Table 2.--An example of a tabular listing depicting Standing Biomass and Renewable Forage Production by land ownerhsip for selected grazing allotments.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

for grazing allotments based on which of the five basic quad groups each grazing allotment was located. Biomass classes were aggregated for grazing allotments to derive total metric tons of biomass types (table 2). These tabular reports were sent to the BLM Desert Plan Staff for inspection and approval.

The biomass figures when converted to AUMs were governed by additional BLM procedural criteria derived from conventional sources. An area was not allocated if: it was greater than four miles from water; had less than 25 pounds of forage per acre; and as mentioned earlier, greater than 25% slope.

OBSERVATIONS AND RESULTS

Since the inception of the Landsat program in 1972, the literature has seen a wide variety of experiments an demonstrations describing the utility of Landsat data. These experiments have laid the ground work in developing procedures by which Landsat data could be displayed, analysed, and reduced. Furthermore, it has been shown that, while Landsat is an attractive data source in its own right, it has fallen short of the great expectations that many investigators harboured. It became clear that spectral information alone contained too much ambiguity and that several data types needed to be integrated in order to model complex landscapes reasonably well. In the case of the CDCA, Landsat worked well in delivering a qualitative interpretation of the desert in terms of broad vegetation classes at relatively little expense, the basic product being the 28 class vegetation map. It was found necessary to quantify the generalized Landsat classification in terms of biomass production with the specific information obtained from the low level aerial photo transects in order to increase the utility of this data for input to the CDCA Plan.

The results of this project, statistics and estimates for range carrying capacity for grazing allotments, have been used as basic data for the California Desert Conservation Area Plan. This has been an actual application funded and designed by the BLM, not an experiment or demonstration. The entire budget for all sections of the Plan was on the order of $8 million with approximately $200 thousand devoted to Landsat based technology developed at JPL. The duration of the project was approximately 2 1/2 years.

One of the mandates of the Act is to provide for monitoring and periodic updates of the data. In the future, such updating will be made easier since the data base is already compiled and computer compatible. Barring any major climatic changes resulting in large changes in perennial plant distributions, the same Landsat data could be used with updated transect flights. It necessary, subsequent Landsat scenes could be integrated with ease into the existing data base.

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COSMIC
Computer Center
112 Barrow Hall
University of Georgia
Athens, Georgia
Telephone: (404) 542-3265

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RESUMEN

El Departamento de la Administración de Tierras (BLM) en el estado de California debe, por mandato del Congreso, preparar e implementar un comprensivo plan administrativo de múltiple uso y largo alcance para los 25 millones de acres del Area de Conservación del Desierto de California (CDCA) y proveer en el plan protección y uso apropiado para los 12,1 millones de acres de tierras públicas administradas por el BLM en el CDCA. Este documento enfoca en los métodos usados en el inventario de la vegetación y producción de forraje para pastoreo de ganado para el Plan.

Una variedad de fuentes de información convencionales y de percepción remota, fueron usadas para el inventario de la vegetación. Primeramente, un mosaico de diez escenas fué compilado en una proyección conformal Lambert y re-examinado a 80 metros por 80 metros de picos de elevación. Corrección de intensidad fué hecha por medio de una lámina de goma para aliviar abruptos cambios de intensidad en los pliegues laterales. El mosaico del Landsat en cuatro bandas espectrales fué segmentado en 22 cuadrángulos de 1° de longitud por 1° de latitud para una computación eficiente. Información digital del terreno obtenida de la Agencia de Mapas para Defensa (DMA) fué registrada en cada uno de los 22 cuadrángulos para la CDCA. Cada uno de los cuadrángulos del Landsat fué clasificado en 100 clases y con la ayuda de la registrada información digital del terreno, fueron reducidas a 28 clases de información general de la vegetación.

Para convertir a cantidades la clasificación cualitativa del Landsat y la utilidad de la información del Plan, vuelos

transeccionales de bajo nivel fueron hechos a través del CDCA. Cada transección fué localizada y registrada en los cuadrángulos de los mosaicos clasificados del Landsat. Las transecciones de bajo nivel fueron interpretadas para obtener los valores de la existente biomasa y de la producción para forrajeo. Esos valores fueron luego asignados a las clasificadas rúbricas espectrales residentes en las transecciones y extrapoladas a través del CDCA.

Mapas representando los límites de la propiedad territorial y los de las asignaciones para pastoreo fueron digitalizados y registrados en las 22 clases espectrales (biomasa) de los cuadrángulos. Los valores de biomasa fueron agregados a la propiedad territorial (pública versus privada) y las asignaciones para pastoreo. Los agregados fueron estratificados en categorías de tres declives con la ayuda de la información digital del terreno. Reportes tabulares de la capacidad de sostén del terreno fueron generados y usados como datos básicos para el Plan.

Percepción Remote de la Vegetación de la Zona Arida Poblano-Veracruzana, México[1]

Diego Fabián Lozano García[2]

RESUMEN.- Se estudiaron las condiciones del uso actual del suelo en la cuenca endorreica de Perote-Libres, México. Utilizando una imagen del satélite Landsat; procesándola con el SIADIS de la SARH y el sistema ERMAN II de IBM, se identificaron 10 clases espectrales correspondientes a matorrales, bosques cultivos y lagunas. Resultando un mapa del uso actual del suelo.

Las zonas áridas y semiáridas se extienden en aproximadamente la mitad de los países del planeta, abarcando un tercio de la superficie terrestre. Las áreas cuya aridez es producida por la sombra de lluvia de macizos montañosos -tales como las regiones semiáridas del oeste de los Estados Unidos y del altiplano mexicano-, presentan los problemas comunes a todas las zonas áridas del mundo; la fragilidad de sus ecosistemas y el peligro de desertificación.

El avance de los procesos de desertificación en las zonas áridas y áreas marginales, representa un problema que plantea la necesidad de contar con inventarios y sistemas de vigilancia, que brinden información en forma eficiente y adecuada sobre la dinámica y magnitud del fenómeno.

"Lo que se necesita claramente, es una serie de evaluaciones de las técnicas apropiadas de los satélites, incluyendo estudios de viabilidad científica y análisis de costo-beneficio. Una vez probada la viabilidad científica, la evaluación podría tratar de determinar el sistema óptimo para la generación de la información requerida, ya sea un sistema de satélites, terrestres o mixto" (SCEP, 1976).

Con esto en mente y ante la necesidad de contar con mapas que reflejen las condiciones de uso actual del suelo en zonas con alta presión demográfica, con riesgo de desertificación y tomando en cuenta los problemas a los que se enfrentan los especialistas a realizar estos tipos de mapas (costo de la información y tiempo requerido para el análisis); se decidió realizar un mapa de la vegetación y el uso actual del suelo en la cuenca endorreica de Perote-Libres; utilizando las técnicas de análisis digital de imágenes multiespectrales del satélite Landsat I.

ZONA DE ESTUDIO.

La cuenca endorreica de Perote-Libres se encuentra enclavada en los Estados de Veracruz y Puebla, entre los paralelos 19° 10' a 19° 40' N y los meridianos 97° 10' a 97°45' O. Presenta un clima semiárido templado con verano lluvioso, del tipo BS,(kw"(w)(i')) según la clasificación de Koppen modificada por García (1973). Existe una extensa planicie con suelos de aluvión cuya altitud varía entre 2300 y 2400 m.s.n.m. Se encuentran numerosos cerros de origen calcáreo, con dirección general de suroeste a noroeste, y altitudes hasta de 2550 m.s.n.m. Además existen formaciones de origen igneo en forma de derrames de basaltos, conos volcánicos o afloramientos intrusivos riolíticos con alturas hasta de 2950 m.s.n.m. (fig. 1).

Estos factores y los distintos manejos que el hombre hace de la tierra, condicionan el establecimiento de varias comunidades vegetales y tipo de uso del suelo. En general, en los suelos planos domina la agricultura temporalera, sembrándose trigo, avena y maíz principalmente; en algunas partes muy localizadas encontramos agricultura de riego. En los derrames basálticos (llamados malpaís) se establecen comunidades donde las especies dominantes son *Nolina parviflora* y *Opuntia robusta*. En las elevaciones calcáreas, además de *Nolina* encontramos a *Agave obscura* y *Hechtia roseana*. En las zonas montañosas se presentan bosques de pinos y de cipreses. En la parte suroeste, donde confluyen los escurrimientos de agua de las montañas se, establece una comunidad de plantas halófitas dominada por *Portulaca oleracea*.

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[1]Trabajo presentado en el Seminario de trabajo "Inventario de recursos naturales de zonas áridas, La Paz, Baja California, MEXICO. Noviembre 30-Diciembre 6, 1980.

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Figura 1. Mapa Topográfico y de Localización.

FUENTES DE INFORMACION Y SISTEMAS DE ANALISIS

Para la clasificación del uso del suelo se utilizó una imagen del satélite Landsat I, obtenida el 25 de mayo de 1973, número de órbita/fila 26/47 y número de identificación NASA ERTS E 1306-16231.

El análisis digital se realizó con el SIADIS (Sistema de Interpretación Automática de Imágenes de Satélite) de la Secretaría de Agricultura y Recursos Hidráulicos del Gobierno Mexicano y el sistema ERMAN II del Centro Científico IBM para América Latina.

Para realizar los análisis de agrupamiento o conglomerados, se utilizó un algoritmo iterativo llamado ISODATA, el cual permite determinar los valores estadístico (media y desviación estandar) de los grupos clasificados; así como la distancia estadística entre los grupos.

Las clasificaciones supervizadas se realizaron con un algoritmo de máxima verosimilitud, el cual utiliza como entrada, la información del valor de media y desviación estandar de campos previamente identificados y asignados a una clase.

PROCEDIMIENTO DE ANALISIS Y VERIFICACION

En un área de prueba que cubre una superficie de 209,795 hectáreas, se aplicaron 3 diferentes procedimientos para delimitar los campos de entrenamiento.

Primero se elaboró un análisis de conglomerados del 60% del área de trabajo, considerando 40 clases espectrales. El resultado de esta primera clasificación se coloreó a mano e interpretó visualmente en el campo.

Posteriormente se realizaron varias pruebas utilizando el mismo algoritmo pero en zonas más reducidas, -de 50 a 100 elementos de lado-. Se realizaron 12 pruebas de este tipo en 5 áreas diferentes, las cuales no fueron cubiertas con el primer análisis.

Los mapas generados con este método se verificaron con fotografías aéreas; se calculó la separabilidad estadística de los grupos así como los valores espectrales de media y desviación estandar en cada banda.

Con la información generada en la fase anterior se delimitaron los campos de entrenamiento para cada una de las clases identificadas en el terreno. Los campos se delimitaron con dos diferentes métodos.

a) Sobre una imagen de falso color desplegada en la pantalla, se delimitaron los límites por medio del cursor electrónico, para definir los campos de la clase AGUA.

b) En los mapas obtenidos en las primeras fases se delimitaron campos, determinando el valor de línea/columna para cada uno de los vértices de dichos campos. Los criterios seguidos para la delimitación fueron: la homogeneidad estadística, la separabilidad de las clases y la verificación en el campo y las fotografías aéreas.

En seguida se calcularon los valores estadísticos (media y desviación estandar), de cada uno de

los campos y clases para las cuatro bandas de la imagen. Estos valores se utilizaron como base para la clasificación, la cual se realizó en todo el campo de prueba, así como en los de entrenamiento (tabla 1).

Tabla 1.- Estadisticas espectrales de los campos de entrenamiento de las clases identificadas.

CLASES	CANALES 4	5	6	7
Izotal (IZOT)				
Media	34.37	32.19	35.34	17.38
Desviación estandar	1.31	1.60	1.60	1.10
Nopalera-Matorral (NOPL)				
Media	40.73	41.98	42.46	20.12
Desviación estandar	1.39	1.65	2.05	1.19
Bosque de Cipreses (BOCI)				
Media	29.00	25.26	30.19	15.39
Desviación estandar	1.10	1.34	1.50	0.97
Bosque de Piñonero (BOPP)				
Media	33.08	29.31	35.92	17.85
Desviación	2.30	3.52	3.07	1.29
Bosque de Pino (BOPI)				
Media	25.63	21.28	33.39	18.30
Desviación estandar	1.43	1.85	2.74	1.84
Vegetación Halófita (VHAL)				
Media	53.55	57.66	51.24	20.57
Desviación	2.47	2.87	2.77	1.48
Cultivo de Temporal (CULT)				
Media	56.31	60.60	55.08	22.84
Desviación estandar	2.42	2.45	2.40	1.31
Cultivo de Riego (CULR)				
Media	34.60	28.92	63.61	35.79
Desviación estandar	4.51	7.73	7.79	6.45
Pastizal (PAST)				
Media	45.73	59.78	52.68	24.53
Desviación estandar	2.30	3.52	3.07	1.29
Lagunas (AGUA)				
Media	35.16	15.79	8.17	1.66
Desviación estandar	1.93	1.36	2.42	1.58

El trabajo de campo se realizó simultáneamente al análisis de la imagen y consistió de 3 fases. La primera correspondió a un reconocimiento general de la zona por medio de recorridos terrestres, vuelos en avioneta y una fotointerpretación la imagen de satélite. Con la información obtenida en esta primera fase se localizaron con precisión los futuros sitios de muestreo de vegetación y suelo.

Los muestreos en el campo se realizaron con el objeto de determinar los tipos de vegetación o condiciones de uso del suelo que aparecieron en las clasificaciones; ya que la información existente para la zona, sólo cubría un área pequeña correspondiente al Estado de Veracruz (Ramos y González, 1972), o bién era muy general (Soto, et al., 1977).

Para lograr esto, una vez ubicados los sitios de muestreo, se utilizaron distintos métodos dependiendo de la fisonomía y estructura de la comunidad.

En aquellos sitios de comunidades muy abiertas con escasa cobertura y formas arbustivas y crasirosetulifolias se determinaron los siguientes atributos:

-Densidad
-Frecuencia
-Cobertura

Para aquellas comunidades arboladas con cobertura entre 40 y 100%, además de los tres valores antes mencionados, se determinaron los valores de: distancia media entre individuos; número de individuos en 100 metros cuadrados; número de individuos de cada especie por cuadrante o por 100 metros cuadrados; área basal media; frecuencia, densidad y dominancia absoluta y relativas y finalmente el valor de importancia siguiendo el método de cuadrantes propuesto por Batcheler (1971).

Paralelamente los muestreos de vegetación se realizaron colectas de suelo en puntos diferentes, cubriéndose los grupos mapeados de los que no existía información de este tipo. Las muestras se tomaron hasta 60 cm de profundidad (donde la roca madre lo permitía), con intervalos de 15 cm para cada una.

Los tipos de vegetación y condiciones de uso actual del suelo encontrados, así como algunos datos medioambientales se muestran en la tabla 2.

La tercera fase del trabajo se realizó para determinar la precisión de la clasificación y la cartografía de los distintos grupos mapeados. Se realizó una verificación de acuerdo a los criterios propuestos por van Genderen, Lock y Vass (1978), que proponen un número definido de puntos de verificación en función del nivel de precisión que se desee obtener.

La clasificación obtenida se verificó visualmente en la pantalla, reconociendo los distintos grupos mapeados y correlacionando el resultado con la información de campo y las fotografías aéreas; además se realizó una prueba de "sumario de clases" la cual determina porcentualmente la "pureza" de los campos de entrenamiento al asignar cada elemento de los campos a la clase que le corresponde estadísticamente. Con esta prueba se eliminaron los campos cuyo porcentaje era menor del 90%. En aquellas clases que poseían más de 2 campos de entrenamiento con porcentaje mayor del 90%, se eliminó el campo con menor valor de exactitud. Para las clases cuyos campos poseían un valor por debajo del 90%, se redefinieron, ya sea reduciéndolos o creando nuevos campos.

Con los campos así definidos se realizaron clasificaciones hasta obtener un resultado adecuado (fig 2), el cual se verificó siguiendo el método propuesto por van Genderen, (opcit). Esta comprobación se realizó fijando puntos al azar en la pantalla, determinando la clase a la que pertenecía, ubicándola en las fotografías aéreas escala 1: 50 000 y realizando la fotointerpretación del uso del suelo en el terreno con un estereoscopio de espejos. En los casos que fue necesario se realizaron salidas al campo para su verificación.

Tabla 2.- Tipos de vegetación y uso del suelo y condiciones medioambientales.

	GEOLOGIA	SUELO			TOPOGRAFIA
		pH	Textura	Materia Orgánica	
IZOT	Igneo Extrusivo Terciario	Neutro	Franco-limosa	Baja	Microtopografía accidentada, suelo escaso.
	Caliza Cretácica	Fuertemente alcalino	Franco-arenosa	Media	Pendiente moderadas, suelo muy escaso
NOPL	Igneo Extrusivo Terciario	Neutro	Franco-limosa	Media	Microtopografía accidentada, perturbación por pastoreo.
	Caliza Cretácica	Medianamente alcalino	Franca	Media	Pendientes moderadas, suelo muy escaso.
BOCI	Igneo Extrusivo Terciario	Neutro	Franco-limosa	Media	Microtopografía accidentada, roca madre aflorando.
BOPP	Igneo Extrusivo Terciario	Neutro	Franco-limosa	Muy baja	Suelo relativamente abundante.
BOPI	Igneo Extrusivo Terciario		Franco-arenosa		Suelo abundante y profundo, a más de 2,700 msnm.
VHAL	Aluvión Cuaternario	Extremadamente alcalino	Arcillosa	Muy baja	Planicie, inundado durante la época de lluvia.
CULT	Aluvión Cuaternario	Medianamente alcalino	Arenosa	Baja	Plano, intervención humana, agricultura temporalera.
CULR	Aluvión Cuaternario	Medianamente alcalino	Arenosa	Baja	Plano, intervención humana, agricultura de riego.
PAST	Aluvión Cuaternario	Medianamente alcalino	Franca	Baja	Planicie o pendiente ligeras.
AGUA	------	------	----	----	Depósitos permanentes de agua.

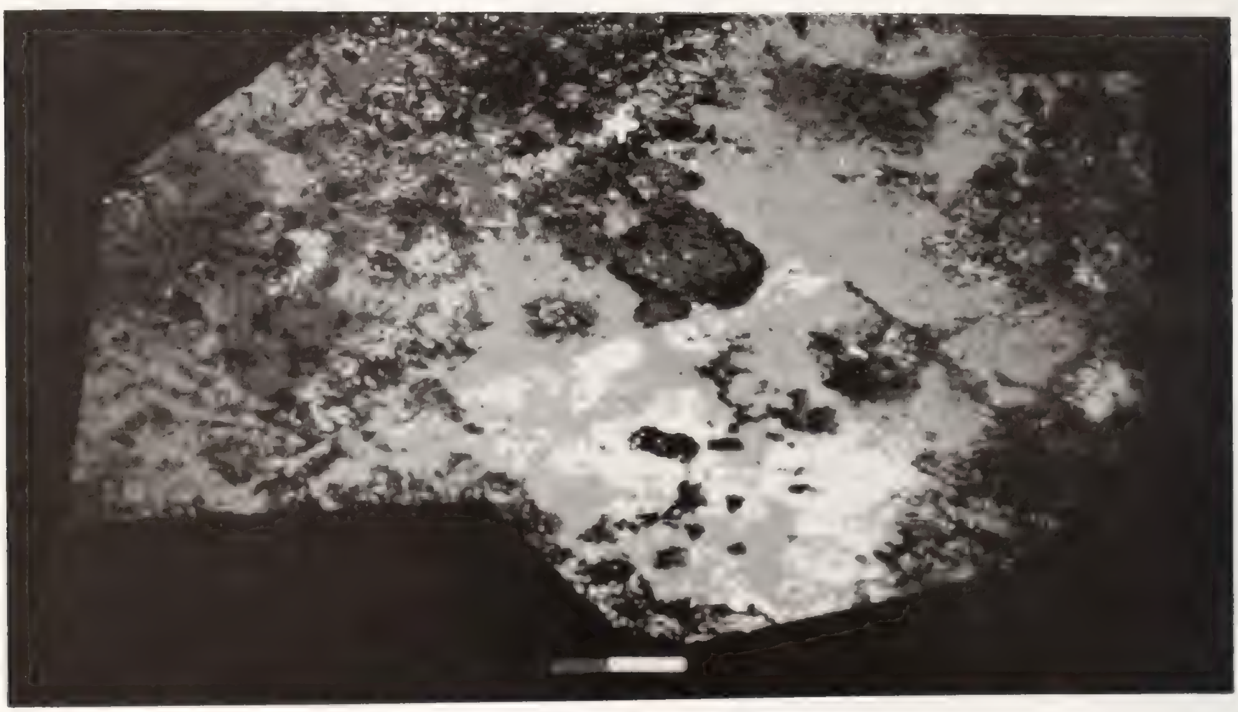

Figura 2.-- Mapa de Uso del suelo y tipos de vegetación

La tabla 3 presenta los grupos identificados, el color con que fueron mapeados así como la superficie que ocupó cada clase.

Tabla 3.- Superficie ocupada por cada clase y codificación de colores.

CLASES	COLORES	SUPERFICIE (Hectáreas)
IZOT	Naranja	20 276.9
NOPL	Café-rojizo	18 440.9
BOCI	Verde	5 556.3
BOPP	Cian	4 757.0
BOPI	Verde obscuro	20 109.1
VHAL	Blanco	5 803.2
CULT	Amarillo	73 181.2
CULR	Rojo	16 109.9
PAST	Oro	45 124.7
AGUA	Azul	436.5

DISCUSION Y CONCLUSIONES

En el caso de este trabajo, dos factores son los que condicionan la presencia de los distintos tipos de vegetación y uso del suelo a nivel regional. Uno es el clima semiárido producido por la sombra de lluvias de la Sierra Madre Oriental. Esta condición sólo es modificada por la presencia de elevaciones montañosas, originando una mayor humedad y menor temperatura a nivel local. El otro factor es de hecho la conjunción del sustrato geológico y el suelo. Así por ejemplo, en los derrames lávicos del terciario, son las variaciones en la textura y el pH básicamente, lo que va a determinar el establecimiento de ciertos grupos vegetales.

Sólo en el caso de la "vegetación halófita" y los cultivos de temporal y de riego es otra la causa. En el primero, la hidrología es el factor fundamental ya que las inundaciones períodicas en esta zona originan suelos con alta salinidad, condicionando el establecimiento de ciertas plantas. En el caso de los cultivos es el manejo de la tierra con sus desmontes, introducción de riego, etc. lo que determina la fisonomía y composición florística del área.

En la tabla 3 se pueden observar los resultados de la prueba de verificación, reconociendose las clases con su porcentaje de precisión.

Respecto a los errores en la clasificación se pueden afirmar que: en el caso de la zona de "Cultivo de Temporal" confundiéndose con las "Vegetación halófita" es debido a la ausencia casi absoluta de vegetación en ambos grupos durante la época de toma de la imagen.

La precisión general de la clasificación fue de 85.9%, con valores que fluctuaron entre el 53.8 y el 100%. El valor más bajo correspondió a la clase "CULR",cultivo de Riego. Esta clase posee una extensión muy limitada en la cuenca (3500 has.), sin embargo no fue posible distinguir estas zonas de otras áreas con cultivos de temporal que quizá fueron prematuramente sembrados.

Tabla 3. Tabla de confusión de la precisión de la clasificación.

	IZOT	NOPL	BOCI	BOPP	BOPI	VHAL	CULT	CULR	PAST	AGUA	Total	% de Precisión
IZOT	28	1	1		2						32	87.6
NOPL		28					2		1		31	90.3
BOCI	1		18		1						20	90.0
BOPP	2			10	4						16	62.5
BOPI					20						20	100.0
VHAL						7	4				11	63.6
CULT						5	25		1		31	80.6
CULR							5	7	1		13	53.8
PAST							2		17		19	89.5
AGUA										5	5	100.0

La zona de vegetación halófita y el área de cultivo temporalero se confunden entre sí y ambas presentan una tendencia mutua de clasificación errónea.

Para la delimitación de los campos de entrenamiento se usó una combinación de métodos; agrupamiento de área extensa, agrupamiento de campos pequeños, interpretación visual. Estos métodos auxiliados con la estimación de separabilidad de las clases, así como del "sumario de clases", nos brindaron un método adecuado de selección de campos, lo que permitió realizar las clasificaciones en un tiempo de analisis relativamente corto (57.59 minutos de CPU).

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ABSTRACT

The conditions of the actual use of the terrain of the river basin of Perote-Libres, Mexico, were studied. Utilizing an image from the Landsat satellite, processed by SIADIS of the SARH, and the ERMAN II from IBM, ten spectral classes were identified corresponding to thickets, cultivated forest, and lagoons, resulting in a map of the actual utilization of the land.

Estimating the Area of Vegetation Types with Landsat and Ancillary Data[1]

David S. Linden, Wayne G. Rohde and Kris G. Bonner[2]

Abstract.--The use of Landsat images and digital data, and ancillary data[3] have proven to be efficient and flexible in estimating the area of vegetation types in arid regions. The methodology and hardware required to utilize these data can be as simple as planimetering a manually interpreted Landsat image or as complex as using the digital data in a multilevel sampling design using a digital image analysis computer system. This paper presents six approaches spanning this range of complexity. Four of these approaches have been applied over a one million hectare area in northwestern Arizona. The accuracy and costs are presented and compared.

INTRODUCTION

The use of remotely sensed data in forest and range resource inventories is not new. Panchromatic aerial photographs were interpreted for use in range surveys in the late 1930's and have been used for many years in forest inventories (Bickford, 1952; Bickford, 1961; Clouston, 1950; Poulton, 1976). Landsat images and digital data, ancillary digital data, and high-altitude aerial photographs are new data sources that can be used independently and in conjunction with large-scale aerial photographs and ground data to efficiently estimate the area of vegetation types. (Nichols and others, 1974; Hoffer, 1975; Gialdini and others, 1975; Krebs and Hoffer, 1976; Harding and Scott, 1978; Rohde and others, 1979a). From these studies it is clear that successful applications of these new data to forest and range resource inventories requires image analysis techniques and sampling procedures that allow quick, consistent and accurate extraction of information in a cost-effective way. The approach used depends on many factors including size of the area to be inventoried, personnel available to the project, availability of computer hardware and software, budget, desired precision of estimates, availability of ground data and large scale photographs, deadlines that must be met, and existing inventory methods.

There are at least six approaches to estimating the area of vegetation types utilizing Landsat and ancillary data. The approach can be as simple as planimetering a manually interpreted Landsat image or as complex as incorporating the digital data into a multilevel sampling design using a digital image analysis computer system. The resource manager faced with inventorying large areas of arid lands should find one of these approaches applicable to his purpose, budget, personnel, and other available resources. The six approaches are:

1. Manual interpretation of Landsat standard false-color composite image at a scale of 1:250,000.
2. Manual interpretation of Landsat enhanced false-color composite image at a scale of 1:250,000.
3. Manually interpreted vegetation type map used as a first level stratification for sample allocation in a multi-level sampling scheme.
4. Computer classification of digital Landsat and digital elevation data.
5. Computer classified data used as a first level stratification for sample allocation followed by a stratified cluster sample.
6. Computer classified data used as a first level stratification for sample allocation followed by a two-stage stratified cluster sample with double sampling.

Approaches 1, 2, 4, and 5 have been applied over a one million hectare area in northwestern Arizona as part of a cooperative project between the Bureau of Land Management (BLM) and the U.S. Geological Survey's EROS Data Center. Approaches 1 and 2 are described in detail by Bonner, 1980. Approaches 4 and 5 are described in Rohde and others, 1979b. This paper summarizes and compares the results of these studies emphasizing the precisions that were obtained, the resulting costs, and the resources required by each approach. In addition, two other approaches are presented that could increase precision by incorporating additional ground data.

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[1] Paper presented at the Arid Land Resource Inventories workshop. LaPaz, Mexico, November 30 - December 6, 1980.

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[3] Examples of ancillary data are digitized ownership boundaries, digital terrain models, and digital soil maps.

THE STUDY AREA

The study area, located in Mohave County in the northwest corner of Arizona, is bounded on the west and north by Nevada and Utah respectively, on the east by 113° longitude and on the south by the Colorado River.

The Colorado River is also the major drainage for the region. The area is roughly 300 km northwest of Phoenix, Arizona, and 88 km southeast of St. George, Utah.

The study area is characterized by broad valleys separated by hills and mountains. The lowest point in the area is the Virgin River in the northwest corner. Elevation rises rapidly from this point to the Virgin Mountains and Grand Wash Cliffs, both on the western side of the site, which are oriented from north-northeast to south-southwest. The Virgin Mountains rise to elevations above 2,300 m and the Grand Wash Cliffs rise at the Shivwits Plateau to 1,800 m. The other major topographic feature in the area, the Hurricane Cliffs, cuts through the east-central part of the area in a north-south direction and rises to an elevation of nearly 1,800 m. The highest point in the study area is Mt. Trumbull, in the southeast corner of the site, with an elevation of 2,447 m.

The study area has a climate of low precipitation, moderate temperatures, plentiful sunshine and low humidity. Mean annual precipitation ranges from about 13 centimeters along the Colorado River to 46 centimeters or more in the Virgin Mountains. About one-half of the annual precipitation occurs from December through March and is produced primarily by storms from the Pacific Ocean that have passed over the continental margin along the southern California coastline. Snow falls occasionally during the winter months, but lingers only at higher elevations. Temperatures during the winter months normally reach 9°C to 17°C during the afternoon and drop to near freezing at night. Summer high temperatures range from 31°C to 42°C during the afternoon and are typically accompanied by low humidity.

The vegetation at the lower elevations is primarily Mohave Desert (or hot desert) types characterized by creosote bush (Larrea tridentata) and bursage (Ambrosia dumosa). The Mohave Desert type diminishes on cooler, more mesic sites, which are dominated by Great Basin Desert (or cold desert) types such as big sagebrush, and pinyon-juniper woodlands (Pinus monophylla and Juniperus osteosperma). Blackbrush (Coleogyne ramoissima), often considered an intermediate type between hot and cold desert types, is also present. Broad, rolling valleys in the east-central portion of the study site, west of the Hurricane Cliffs, at elevations around 1500 m, support a grassland type, characterized by Galleta (Hilaria jamesii), blue and black gramma (Bouteloua gracilis and B. eriopoda), and Indian ricegrass (Oryzopsis hymenoides), with scattered shrubs. Mountain shrub types and ponderosa pine (Pinus ponderosa) stands are present at the higher elevations. This area provides important habitat for a wide variety of wildlife. Other demands on the limited resources in the area include livestock grazing, recreation, mining, logging, and homesites.

APPROACH 1

Manual Interpretation of Standard Landsat False Color Composite Image

The Landsat image was acquired on August 26, 1977. Interpretation was done on a 1:250,000-scaled print that was enlarged from the 1:1,000,000 scale master color transparency archived at the EROS Data Center (EDC) in Sioux Falls, South Dakota.[4] An interpretation key similar to that described by Tueller and others (1975) was used to train the interpreter to recognize different cover types. The interpreted cover types interpreted were based on a hierarchical vegetation classification framework developed by BLM and EDC resource scientists. The framework is similar to the one adopted by the U.S. Geological Survey (Anderson and others, 1976). The interpreted vegetation and land cover types were: cropland and pasture, coniferous forest, evergreen woodland (pinyon-juniper), deciduous woodland, Mohave Desert Shrub, Great Basin Desert shrub, plains grassland, barren land, and water.

The delineation and classification of cover types was made on clear acetate material overlaying the Landsat images. A 260 hectare minimum mapping unit was used. A final cover-type map was made by manually transferring delineations from the interpretation overlay to an overlay of mosaiced U.S. Geological Survey 1:250,000 scale topographic maps of the project area. This was a relatively easy task because the Landsat image is nearly planimetric.

The area mapped included approximately 1,000,900 hectares. Within this area was a 628,178 hectare tract comprising the Grand Wash planning unit of BLM's Arizona strip district. The final map was used to estimate the area of each of the eight cover types

[4] The U.S. Geological Survey's EROS Data Center is where all Landsat data are processed, archived, and made available for purchase by the public. For ordering information, contact User Services, EROS Data Center, Sioux Falls, SD, 57198.

within the Grand Wash planning unit. The area of each cover type was estimated using an electronic planimeter to planimeter each polygon three to five times. The average of the planimetered measurements were used to estimate the area. The results are shown in Table 1.

Approach 1 is the simplest and least expensive of the six approaches. The equipment required to perform the analysis is minimal. The only specialized piece of equipment required is a digital planimeter. The analysis required 259 work hours (Table 2) and cost $3,321. Based on the size of the Grand Wash planning unit, the analysis cost one half cent per hectare (Table 3).

The primary requirement for successful application of approach 1 is a competent-experienced interpreter. The interpreter must be familiar with the ecology of the vegetation types found in the area. He must be able to relate color and texture from the Landsat image to the vegetation type. When this is inadequate to delineate and classify the cover types, he must utilize terrain data and ecological relationships to aid in the interpretation. The accuracy of the area estimates are determined by the accuracy of the interpretation. Any error in interpretation will result in an error in area estimates.

Table 1. Estimated area of cover types within Grand Wash planning unit using approaches 1 and 2. Total area is 628,178 hectares.

Cover Type	Approach 1 Standard Landsat Image	Approach 2 Enhanced Landsat Image
	%	%
1.1 Cropland and Pasture	<1	<1
2.1 Coniferous Forest	<1	<1
3.1 Evergreen Woodland	43	30
3.2 Deciduous Woodland	<1	<1
4.1 Mohave Desert Shrub	22	21
4.2 Great Basin Desert Shrub	25	41
4.3 Mountain Shrub	1	1
5.1 Plains Grassland	8	6
6. Barren Land	<1	<1
7. Water	0	0

The main shortcomings of this approach are that there is no way of correcting for misinterpretations and no way of calculating confidence intervals for the area estimates. The goodness of these estimates can only be expressed intuitively by the interpreter based on his experience. However, in the Arizona study the accuracy of the cover type maps was determined using large scale photography (1:6,000 scale) as a base for a sampling scheme (Bonner, 1980). The results indicate that while the map was 83% (3% standard error) correct most of the cover types areas were over estimated or underestimated by a considerable margin (Table 4).

Table 2. Work hours required for analysis of entire area using approaches 1 and 2.

Task	Work Hours: Approach 1 Standard Landsat Image	Work Hours: Approach 2 Enhanced Landsat Image
Development of Vegetation Classification Framework	60	60
Development of Image Interpretation Keys	71	71
Cover Type Interpretation	11	12
Production of enhanced Landsat Image (computer operator)		16
Preparation of draft copy cover type maps	27	27
Planimetering Maps	30	30
Administrative	60	60

Table 3. Costs for analysis of entire area using approaches 1 and 2.

Item	Approach 1 Standard Landsat Image	Approach 2 Enhanced Landsat Image
Labor @ $9.50/hr.	$2,461	$2,622
Landsat Images	100	3,101
Cover Type Overlay Production (drafting & photo lab costs)	160	160
Travel to study site for 5 days	600	600
Totals	$3,321	$6,483
or	($.005/ha)*	($.01/ha)*

*Based on Grand Wash planning unit size of 628,178 hectares.

Table 4. Estimated bias of area estimates based on interpretation of 1:6,000-scaled photographs of 117 sample units. Bias is the estimated commission error in percent minus the estimated omission error in percent.

Cover Type	Approach 1 Standard Landsat Image	Approach 2 Enhanced Landsat Image
Evergreen Woodland	-20	-2
Mohave Desert Shrub	0	3
Great Basin Desert Shrub	27	0
All other cover types	-21	0

APPROACH 2

Manual Interpretation of Enhanced Landsat False Color Composite Image

The Landsat image used in this approach was produced from the same digital data as the image used in approach 1. However, the digital data were computer processed to minimize radiometric and to increase contrast. A detailed discussion of the enhancement techniques that were used can be found in Rohde and others (1977). The enhanced digital data were used to make a 1:1,000,000 scaled-master color transparency. The master transparency was used to generate a 1:250,000 scaled-color print used in the interpretation.

The enhanced image was interpreted by the same person who interpreted the standard image. The same interpretive methods and techniques were applied to both images. Using the same methods of planimetering as in approach 1, area estimates for each cover type were made (Table 1).

The application of approach 2 requires the availability of enhanced Landsat data. It cost \$3,253 to produce the enhanced image which doubled the cost of approach 2 over approach 1. The total cost was \$6,483 which, based on the size of the Grand Wash planning unit, works out to be \$.01 per hectare (Table 3).

If enhanced data are readily available, approach 2 is as simple and nearly as inexpensive as approach 1. Both approaches share the shortcoming of offering no way for correcting misinterpretations and no way of calculating confidence intervals for the area estimates. However, in the Arizona study, the large-scale photo accuracy assessment indicated that although the map produced was not significantly more accurate (α = .05) than the map from the standard image, there was very little bias in the area estimates of the individual cover types as compared to the high bias as found in approach 1. Therefore, if the alternatives are to use approach 1 or approach 2, enhanced Landsat images should be used when estimating the area of cover types.

APPROACH 3

Manually Interpreted Vegetation Type Map Used as a First Level Stratification for Sample Allocation in a Multi-Level Sampling Scheme

This approach was not used in the study area but is presented here as a method that would allow the resource manager to apply the low cost methods of approach 2 to a sampling design that would provide statistically sound estimators with confidence intervals. In this approah, misinterpretations by the interpreter do not bias the area estimates but do decrease sampling efficiency. Therefore, this approach overcomes the main shortcomings of approach 2.

In this approach, the manually interpreted vegetation type map would be used to stratify the study area. Stratification means the separation of a mixed population of vegetation types into its component sub-populations, which are relatively more homogeneous than the parent population. This results in each sub-population having a lower coefficient of variation[5] than the parent population. These lower coefficients of variation allow one to estimate a population mean at a specified precision, using fewer samples than if one had not stratified. Stratification also leads to measurements more closely approximating the normal distribution. Stratification allows one to take less ground samples for a pre-determined precision, and since field work is the most expensive part of inventory, cost is reduced.

Application of this approach assumes the resouce manager is currently using some type of ground survey for vegetation types and can be used with almost any type of ground sampling whether plot, point, transect, or strip. After the manually interpreted cover type map is prepared and strata are defined, the inventory specialist determines how many sample units to allocate to each strata. The allocation method used depends on how much is known about the variation within each strata. If the variation is assumed constant

[5] The coefficient of variation is the population standard deviation expressed as a percentage of the mean (Freese, F., 1962).

over all strata, then sample units are allocated proportional to the size of each strata. If the coefficients of variation are known or can be estimated for each strata, then Neyman allocation is used (Barrett and Nutt, 1979, p.141). If the relative cost of obtaining ground data in each strata is known, then optimum allocation is used (Barrett and Nutt, 1979, p.141). The total number of samples required is determined by the required precision, the allocation method used, and the variation of the sub-populations. For a complete statistical treatment of stratified sampling see Barrett and Nutt, 1979; Cochran, 1977; and Freese, 1962.

After the number of samples for each strata has been determined, the sample plots can be chosen either randomly or systematically using methods described by Lund (1979) or by Rosenfield and Melley (1980). These samples are then ground visited using existing inventory techniques.

APPROACH 4

Computer Classification of Digital Landsat Data and Digital Elevation Data

A computer compatible tape (CCT) of Landsat scene 2947-17074 acquired August 26, 1977, was used for the digital processing. The data were analyzed using an interactive analysis procedure and a maximum likelihood classification algorithm. A controlled clustering technique, similar to that described by Fleming, Berkebile and Hoffer (1975), and an unsupervised clustering technique described by Rohde (1978), were used to derive training set statistics for use with the classification algorithm. The training set statistics and Landsat data were entered into a maximum likelihood classifier. This resulted in each pixel in the study area being classified into one of 76 computer classes. The classified image was displayed on an interactive-color monitor and each computer class was systematically displayed. Existing color-infrared aerial photographs and older vegetation maps of selected areas were used to assign each computer class to one of nine land cover classes.

Digital elevation data over the study area were acquired from the National Cartographic Information Center (NCIC). The data were registered to the classified image and elevation/vegetation criteria were established. Elevation decision rules were established to reclassify the 76 computer classes into 83 computer classes using a two variable parallelepiped classifier as described by Lillesand and Kiefer (1979, p. 464). Each of the 83 computer classes was then assigned to one of eight land cover types. Since the data were in digital form, it was easy to count the number of pixels (50 by 50 meter cell) that were classified into each of the cover types. This was then tabulated for the entire million hectare area (see Table 5).

Table 5. Tabulation of area estimates based on digital processing of Landsat data and digital terrain data.

Cover Type	Area (hectares)	Area (percent)
Coniferous Forest	9,073	<1
Evergreen Woodland	171,464	17
Deciduous Woodland	817	<1
Mohave Desert Shrub	165,131	17
Great Basin Desert Shrub	610,559	61
Mountain Shrub	8,330	1
Grassland	33,449	3
Cropland and Pasture	1,333	<1

In order to implement this approach (or approaches 5 and 6 which follow), it is necessary to have access to a digital computer system complete with all of the hardware and software required to perform digital image analysis and classification and trained data analysts must be available to perform the analysis. The costs to perform the analysis using this approach are shown in Table 6. The total cost was $69,881 which, based on the entire 1,000,900 hectare study area, works out to be $.07/hectare.

Table 6. Costs to estimate area of vegetation types using digital Landsat data and digital elevation data.

Item	Cost
1. Direct Labor - 2,084 hrs. @ $9.50/hr.	$19,798
2. Travel	7,500
3. EDC products and tapes	5,000
4. Computer Cost	37,583
Total	$69,881
or	($.07/ha)*

*Based on the entire 1,000,900 hectare study area.

This approach has the same shortcomings of approaches 1 and 2. There is no correction made in the area figures for misclassification and there is no way to construct a confidence interval for the area estimates.

APPROACH 5

Computer Classified Data used as a First Level Stratification for Sample Allocation Followed by a Stratified Cluster Sample

This approach, as applied to the study area, used the computer-derived data to stratify the study area just as approach 3 used the manually interpreted cover type map to stratify. After stratification, a randomly selected cluster sample of pixels was allocated to each strata and 1:6,000-scaled color photographs were acquired over each cluster. Misclassifications by the computer do not bias the area estimates but can decrease the efficiency of the sampling. Also, statistically valid confidence intervals can be calculated for each area estimate.

To apply this approach, the classification image was first divided into 8 pixel by 8 line clusters. Each cluster was then assigned to a strata based on the predominant cover type in the cluster. Funding was available to acquire 147 stereo triplets over the sample clusters. Proportional allocation was used to determine the number of sample clusters chosen from each strata. The computer randomly selected the sample units from each strata and using a flatbed plotter, plotted the sample units on mylar overlays that were registered to 1:24,000 scale topographic maps. Flight lines were then drawn on the maps for use by a private contractor to acquire the 1:6,000 scale color aerial photographs, in stereo, over each sample cluster. Due to bad weather, only 119 sample clusters were actually photographed.

The mylar overlays were also used to transfer the sample clusters onto 1:24,000 scale orthophoto quads. The corners of the sample clusters were then transferred from the orthophoto quads to the 1:6,000 scale color aerial photographs (see figure 1). Each cell within the 8 by 8 cluster corresponds approximately to a Landsat pixel (.405 ha). Each of these cells was photointerpreted into one of the eight resource classes. These data were used with estimators for a stratified-cluster sample to estimate the area of vegetation types (Table 7). A more detailed discussion of the analysis techniques and the appropriate statistical formulaes can be found in Rohde and others (1979a).

The additional cost to estimate the areas using approach 5 over approach 4 was $21,082 (Table 8). This resulted in a total cost of $90,963 which based on the entire 1,000,900 hectare study area works out to be $.091 per hectare.

Figure 1. 1:6,000 scale color aerial photograph with 8 x 8 sampling grid.

Table 7. Estimate of area of wildland vegetation based on a digitally stratified cluster sample.

Cover Type	Area Estimate Hectares	Area Estimate Percent	Standard Error as a Percent of the Area Estimate
Ponderosa Pine	2,513	<1	29
Evergreen Woodland	195,402	19	7
Deciduous Woodland	1,661	<1	41
Mohave Desert Shrub	160,527	16	6
Cold Desert Shrub	603,088	60	3
Mountain Shrub	35,615	4	32
Grassland	8,459	1	35

Table 8. Additional costs to implement approach 5 assuming approach 4 has been completed.

Item	Cost
1. Direct Labor - 956 hrs. \$9.50/hr.	$9,082.00
2. Photo Acquisition Contract	5,000.00
3. Photo Processing and Reproduction	5,000.00
4. Computer Cost	2,000.00
Total Additional Cost	$21,082.00

Approach 5 is applicable when the photointerpreter can call each cell into a resource type without any error. The statistical theory used to construct the confidence intervals assumes negligible measurement error. A misinterpretation by the photointerpreter would be a measurement error and more than just a very few of these would negate the integrity of the estimates and their confidence intervals. If misinterpretations are likely, then ground sampling must be incorporated into the sampling design. This is discussed in approach 6.

APPROACH 6

Computer Classifed Data Used as a First Level Stratification for Sample Allocation Followed by a Two-Stage Stratified Cluster Sample with Double Sampling

In approach 5, the Landsat digital data were used to stratify the area and then 8 by 8 clusters of pixels were sampled using large scale-photographs. However, there was no verification of the accuracy of the photointerpretation. Any errors in photointerpretation would corrupt the statistical validity of the area estimates. If misinterpretations are likely, a two-stage stratified cluster sample with double sampling should be used.

In the two-stage sample, a subsample of cells from each of the 8 by 8 clusters is randomly selected and ground visited. The ground data is then used to adjust the photointerpretation data for misclassifications. This technique and the appropriate statistical formulaes are well described by Wensel (1977).

It was originally planned to apply this approach in the Arizona study area subsampling 4 pixels in each 8 by 8 cluster. However, delays in acquiring the large-scale aerial photography and completing the photointerpretation precluded fieldwork during the 1978 field season. The estimated cost of performing the fieldwork using a helicopter would be about $25,000. This would have raised the total cost to $115,963 which works out to be $.116 per hectare based on the 1,000,900 hectare study area.

SUMMARY

Landsat imagery and Landsat digital data have shown to be cost efficient tools for estimating the area of vegetation types in arid regions. Manual interpretation of Landsat imagery provided area estimates at a cost of $.0053/hectare for standard images and $.01/hectare for enhanced images. The estimates from the standard images were significantly biased while those from enhanced images were unbiased. Manual interpretation of Landsat images should prove to be valuable for stratifying an area prior to conducting an on-the-ground inventory. Digital analysis of Landsat digital data and digital elevation data provided area estimates at a cost of $.07/hectare. This data was in digital form and easy to manipulate and place into a geobased information system. The digital data were also used to stratify the area for cluster sampling using large-scale aerial photographs. The resulting estimates cost $.091/hectare. If photointerpretation cannot be done accurately, a two-stage with double sampling approach can be used at an estimated cost of $.116/hectare.

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RESUMEN

La utilización de imágenes Landsat, data digital y data auxiliar ha probado ser eficaz y flexible en el estimado del área de diferentes tipos de vegetación en regiones áridas. La metodología e instrumentación que se requieren para utilizar esta data puede ser tan simple como la planimetría de una imagen Landsat descifrada a mano, o tan compleja como la de utilizar data digital en un diseño de muestreo de niveles múltiples usando un sistema de computadora para el análisis de imagen digital. Esta presentación ilustra seis enfoques que abarcan esta gama de complejidades. Cuatro de estos enfoques han sido utilizados sobre un millón de hectáras en el noroeste de Arizona. Se discuten y se comparan la precisión y los costos de estos enfoques.

Applicability of Large-Scale Aerial Photography to the Inventory of Natural Resources in the Sahel of Upper Volta[1]

Kersten F. Panzer and Bruno Rhody[2]

Abstract.---A fixed-base 70 mm twin camera system in combination with a 35 mm tracking camera has been used to obtain large-scale aerial photography of lines and clusters of ground plots on range and wood lands in the Sahel of Upper Volta. Preliminary results indicate that this equipment can be successfully applied to the inventory and monitoring of natural resources in arid regions using multiple regression estimators with stratification as sampling design. Inventory results are needed for defining long-term land-use regulations in an attempt to halt desertification and to identify suitable sites for improved management practices such as agro-forestry systems.

INTRODUCTION

The problem in perspective

The Sahel of Upper Volta comprises approximately 37 000 sq. km between latitudes 13° and 15.5° N which is 14 % of the country. In this region live 300 000 people or 5 % of the total population with close to 560 000 head of cattle and 900 000 goats and sheep. The average of 8 people per sq. km appears low but people and animals are concentrated in villages, settlements, around wells and traditional pasturing grounds while remote areas to the north are nearly void.

A mixed livestock/farming economy prevails, sedentary groups practicing dry-farming (millet and sorghum) keeping some cattle, goats and sheep while nomadic groups live from their herds but plant millet on their way north hoping for a modest harvest on their return at the end of the rainy season. Between 300 to 600 mm of rain fall over three months from July to September with strong variations in space and intensity. Eight months of the year are absolutely dry. Potential evapotranspiration is estimated at 1800 to 2200 mm / year.

Health care, veterinary aid and deep wells have favored a strong increase of population growth and herd size, leading to severe over exploitation of wood and range resources. The resulting increase in demand for food and forage had been largely met by extending dry farming into traditional range lands while herdsmen moved further north in search for undisputed pastures. Losses in human lives and heads of cattle during extended periods of drought mean only temporay relief of pressure on the environment because, due to outside assistance, human and animal populations recover faster than the vegetation cover. As a concequence, destruction of the vegetation and erosion of the top soil, commonly called desertification, spread at an alarming rate in Sahelian and Sudan-Sahelian savannas (UN-FAO 1974, Barral 1977). In all, nearly 10 million people in an area of 6.8 million sq. km are immediately threatened by the destruction of their livelihoods, (UNCOD 1977).

Reversing this fatal trend will require the formulation of new land use policies, implying the limitation of the number of people and animals per area unit as a function of the

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carrying capacity of Sahelian ecosystems. For obtaining the necessary data on the state and evolution of natural resources an inventory must be carried out followed by long-term monitoring operations.

The forest and range resource base and its significance in a rural subsistence economy

The Sahel and the adjacent Sudan-Sahel zone comprise a number of well discernible ecosystems whose floristic composition is mainly governed by prevailing soils, inclination and precipitation. These ecosystems are increasingly subject to excessive use by man and his animals. Degradation and destruction of the vegetative cover spread as a consequence of overexploitation, but only to a minor degree due to drought. All ecosystems display a remarkable potential of resilience and regeneration when temporarily protected against cutting and grazing.

In its entire extent this natural resource contributes essentially to the subsistence of the rural population by providing wood for cooking, construction and for sale as a source of cash income; bark, fruit, fibres and leaves are used for nutrional, medical and household needs, many plants provide also valuable forage for cattle, sheep and goats, particularly in the dry season. In all, probably more than 80 species of woody plants are utilized in one or the other way. The overall quantities produced, harvested or marketed escape statistical assessment and are therefore unknown. But wood is the sole source of energy for cooking and from 5 % to 15 % of nutritional intake may seasonably be based on minor forest and range products. This is a significant contribution to survival in a subsistence economy.

The destruction or further significant reduction of this valuable, - and in monetary terms rather stable - resource would in fact spell disaster for a large portion of the rural population, devoid of alternative sources of energy, food and materials. The need for inventorizing the present state of the resource base and for monitoring the evolution for halting desertification is evident if efficient measures for protecting or improving present resources and for building-up reserves shall be defined. In areas with higher rainfall, reserves must be created to allow for a planned evacuation of people and animals when drought threatens. The destruction of the vegetation and the loss of animals and lives can be reduced if preventive measures can be taken in time. Such precautionary planning will be impossible without reliable data being continuously gathered and analyzed.

METHODS AND MATERIALS

Preliminary investigations

In view of this situation, preliminary investigations on the feasibility of an inventory of range and forest resources in the Sahel were initiated as part of the German bilateral aid programme.
Evidently, some form of cost-efficient remote sensing technique had to be used considering the extent of the area, difficulties of access and transport, the low commercial value of the resources and the necessity of repeated, periodic controls of changes. It was then decided to test the applicability of the twin-camera system developed for forest inventory purposes in Germany, under arid land conditions.

In 1978/79 lines and clusters of sample plots were established in cooperation with the National Forest Service in the vicinity of two settlements in the Sahel. The sample plots were subsequently photographed from the air to verify to what extent ground sampling could be replaced by large-scale photo-sampling using a double sampling design, i.e. large-scale aerial photo-sampling and a field survey with a limited number of ground sampling units. Despite a camera failure due to human imperfection, limiting the number of lateral stereo-pairs taken, excellent photographic documents have been obtained from dry and wet season photo-missions. Technical and methodical aspects of the large-scale photo technique have been described by Rhody (1980b) elsewhere in these proceedings and are therefore only briefly summarized below.

Possibly, because of its simplicity and the high evaluation potential, - from simple dot count for cover-typing and relative area estimation to photogrammetric measurement of single tree variables, - this camera combination may be found suitable for similar tasks of inventorizing and monitoring natural, renewable resources in arid regions elsewhere, or, in case of a sudden localized event, for getting quantifiable photo-documents of different scales within a few hours at low cost.

Aerial photography in forestry

Because of the global view provided, aerial photography from its beginning has been a valuable source of information in forestry. However, the navigational and photographic equipment of modern survey aircraft required for flying large-area coverage at rather small scales makes their use for repeated low-level reconnaissance flights too expensive. Besides, the precision of the photography which is useful for cartographic purposes is hardly utilized in forestry but frequently lacks those details essential for vegetation resource surveys. Consequently, investigations with automated amateur camera equipment, light aircraft and helicopters have been carried out by foresters in many countries in order to find a simple, inexpensive but effective means of inventorizing inaccessible forests from the air by photographing sample plots in forests and range lands from low flying altitudes. The technical problems of large-scale aerial photography have been essentially solved during the last 5 years through the advent of automated 70 mm amateur cameras with motorized film transport and diaphragm adjustment. Two basic approaches have been developed:

1) Sequential photography with automatic height and tilt control.

   A group of researchers at the Forest Management Institute in Ottawa, Canada is using the following equipment:

   - a Vinten 70 mm camera
   - radar altimeter
   - a tilt control unit
   - a fixed wing, twin-enginge aircraft as a carrier,-

   for obtaining sequential photographs with 60 % end-lap. The scale of the photographs is determined from the radar altimeter readings taken at the time of exposure and copied into the photo (Aldred and Lowe 1978, Sayn-Wittgenstein et al. 1978).

2) Fixed-base photography using a twin camera system.

   Talts (1977) in Oslo and Rhody (1978 1980a,b) at Hamburg-Reinbek use two Hasselblad cameras with a fixed base, mounted one each under the wings of single-engine aircraft. They obtain lateral stereo-pairs with 90 % overlap and 10 - 15 % endlap, the scale being determined via the fixed base.

The photographic equipment

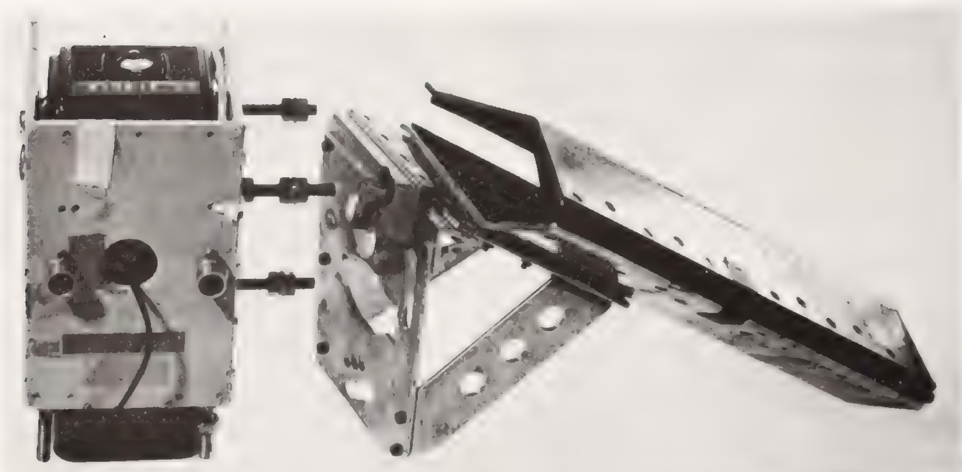
The camera system presented here has been designed by B. Rhody, and has already been successfully tested over plantations in Venezuela and in the Sahel of Upper Volta in 1978/79 (Rhody 1980a,b). The system is based on the concept of fixed-base stereo photography. It consists of two Hasselblad EL 500 cameras with Zeiss Planar f-80 mm lenses for 70 mm film and a Canon F1 35 mm-camera for flight path tracking. All cameras have electric motors for film transport and electrically controlled diaphragm aperture. The two Hasselblad cameras are mounted under each wing of a light aircraft at a distance of 4.10 m from each other (Fig. 1 and 2), the Canon is attached to the right wheel support. Shutters are released synchronously by a synchronizer/intervalometer. Each 70 mm-photo contains also the principal point of its twin, their distance on the photo corresponds to the camera distance of 4.10 m, hence the scale of each photo-pair can be determined and the need for ground truth points is eliminated. This is a necessity, when, beyond qualitative assessment, absolute measurements of cover type area, crown diameter or tree height shall be made.

It is a disadvantage that the Hasselblad cameras presently hold only 5 m of film, equal to about 65 - 70 frames. At an altitude of 400 m this corresponds to a strip 275 m wide and about 16 km long. After that the plane must return to the nearest airstrip for a change of film magazines. In the meantime, the 500 frame-magazine developed for NASA space flights has become commercially available. However, since a least two such magazines are required, the expenditure of US $ 7 500 per unit can only be justified for control flights over an extensive area within the framework of a permanent inventory or monitoring operations.

Frequently, it is rather difficult to determine the exact location of the large-scale photo samples, particularly if salient terrain features are missing. Therefore, the 35 mm camera, which, at the above altitude, holds 250 frames covering 100 km in length and 420 m in width, is activated over a road or a house or any characteristic point represented on the 1 : 200 000 topographic map. With this photo-

strip it is easy to locate the 70 mm stereo-pairs. Again, this camera system has not been designed for large area coverage but for detailed photos of sample plots or sample strips.

Figure 1.--Cessna 150 aircraft with two Hasselblad EL 500 cameras mounted on wing-struts.



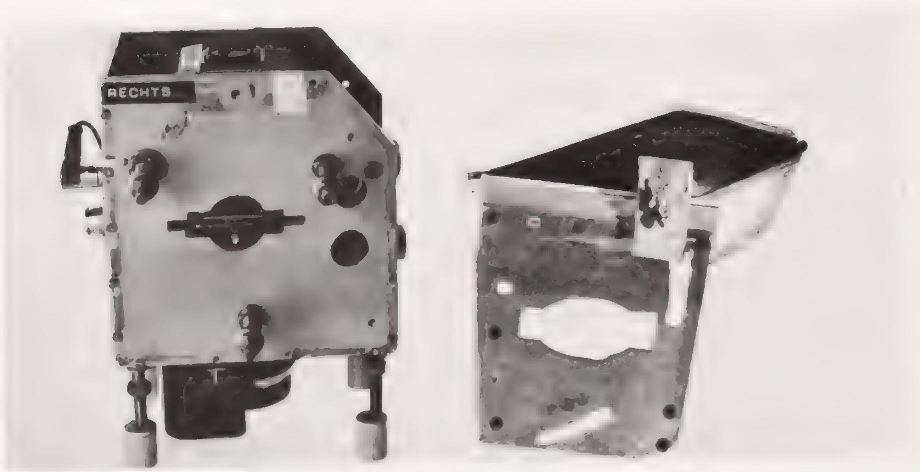


Figure 2 & 3.--Hasselblad EL 500 in housing, with three bolts for fastening and orientation and camera support on clamp for mounting on wing struts of Cessna aircraft.

Camera housings and clamps

Key accessories for rapid installation of the cameras are camera housings and clamps. Both are made from 5 mm (quarter inch) sheet aluminum. An open-top case with the dimensions 155 mm wide, 170 mm deep and 175 mm high, foam-rubber cushioned, houses one camera. A 15 mm long socket screw fastens the cameras to the casing; cuts into the sides are made where necessary for reading of camera dials and functions. Three lateral bolts, washers and nuts serve for attachment of the casing to the clamp (see also fig. 2 and 3). Clamps for Cessna 150/170 planes are made from two aluminum plates 300 mm by 220 mm, machine bent to correspond to the cross-section of the wing-strut, whose profile had been taken with a piece of band-iron. The plates are joined by hinges on the front edge while the rare is closed with 4 bolts and wing-nuts. Again, the innerside is lined with a foam-rubber mat for protection.

The clamps carry a lateral, triangular support to which the bolts of the camera case are fastened. One circular boring and two slots allow for quick orientation of cameras normal to the ground, the slot is needed for inserting or removing the magazine cover plate. A bolt and cross-plate permit to fasten the clamp also to the ring on the upper end of the wing strut, which usually serves for fastening the retaining cable when the aircraft is parked. A step-like, interchangeable assembly of plates is used for the Piper and Maule Strata planes, requiring only differently spaced borings for the bolts holding the camera housing. Electrical cables are wound around the struts, taped to the fuselage where necessary, and enter the cabin beneath the co-pilots door. A hand-made control board unites all incoming cables with the synchronizer/intervalometer and a central 12 volt power supply.

Suitable aircraft for low-altitude missions

With the photographic equipment as described above an airplane for low-altitude photo flights must meet two basic requirements:

1. it must be a high-decker with wings above the cockpit and wing struts for attachment of cameras;
2. the plane must have the capability of flying at speeds as slow as 65 - 75 knots because the cameras have a limit of 1/500 sec. of exposure time. At higher speeds ground movement becomes too fast and the photos are no longer sharp.

The above specifications are met by the Piper PA 12/18, Cessna 150/170, Maule Strata etc., aircraft available at most aeroclubs in the western hemisphere.

Film material

No special films are needed: The Hasselblads use 70 mm Kodak Ektachrome 64 professional daylight film with perforations to obtain positive color transparencies while the Canon is loaded with black and white negative film e.g. Agfapan 400 professional, for obtaining black and white prints. These films are commercially available in 30 m rolls, - 5 m color film and 10 m black and white film fitting into a film magazine, respectively. Processing does not require any special equipment except larger developing tanks and drying racks because films should be processed uncut for recognition of coherent flight strips.

Evaluation and interpretation of photographs

The slides/prints can be evaluated in three ways:

1. by dot-grid count of different cover types;
2. by projection for producing enlarged line drawings or base maps;
3. by stereoscopic plotting and photogrammetric measurements using slides or prints.

To 1: For area estimation the vegetation cover types discernible on the slide or print are delineated with a wax pencil. Slides are then taped on to a luminous table, prints fastened to a glass or metal plate and a transparent dot grid is laid over the photographs. A count is then made of the dots or squares falling into a particular cover type. By setting the total photo area equal to 100 a relative estimate of the share of each stratum can be obtained. For the interpretation of large amounts of photographs the use of an automatic planimeter may be justified.

To 2: When inserted into a standard magnifying apparatus the color-slide can be projected on a sheet of drawing paper for drawing a sample

plot diagram, or for mapping the distribution of cover types using adjacent photos.

To 3.: The 70 mm color stereo-slides may be evaluated with a simple pocket stereoscope, a bridge stereoscope with parallax bar or by means of a second-order stereo-plotter as the Zeiss Planitop F2, modified for 80 mm fixed-base photography (Rhody, 1976). In each case the stereoscopic interpretation increases the amount of information retrievable and with the paralax bar or with the stereo-plotter, absolute measurements of tree height or crown diameter are possible since the scale of the photopair is known.

Ground sampling

The sample tree measurements carried out on aerial photographs have to be adjusted by tree measurements on ground sample plots. In addition, information not obtainable from photographs such as age, increment, bark thickness or volume, must be gathered in the field. The following paragraphs describe the sampling set-up used in the Sahel and the form and size of the sampling unit proposed for a future pilot inventory of forest and range resources.

In 1978/79 lines and clusters of sample plots had been established at four locations in the north of Upper Volta, ecologically defined as southern Sahel. After some experiments a 0.1 ha circular plot (r = 17,84 m) was enumerated every 100 m along a line running north-south over at least 500 m. Later on, a cross 1000 m by 1000 m and a square cluster (tract) of 300 m side length were tested also. The square design was found most advantageous bringing the field crew back to its starting point after enumeration work has been finished. However, surveying a 300 m square cluster may be extremely difficult where dense thornbush prevails so that 100 m side length will be used in the future.

All trees and bushes in a plot have been recorded by polar coordinates as a means of facilitating relocation of the plot at the occasion of a second inventory. In addition, iron rods were burried in the center of the plot. In accordance with suggestions made by French range scientists working in the same area, the inner area of the tract will be used for estimating composition, density and biomass production of the herbage stratum (Boudet and Malacamp 1979).

Form and size of the sampling unit

The sampling unit consists of a square block (tract) of 100 m side-length with 0.1 ha circular sample plots at each corner. Every 50 m a 0.0125 ha circular plot is laid out for the count of regeneration and low plants crippled by browsing. All plants up to 0.30 m height that do not qualify as bushes or trees will be counted. Inside of the perimeter density, composition and above-ground biomass weight of the grass and forb cover are estimated along lines and on 1 m^2 plots (see fig.4).

Measurements of trees and shrubs

Species of trees and shrubs are counted and recorded clockwise, beginning at magnetic north. For all trees two diameters (0.2 m above ground and at breast height (1,30 m), stem height and a total height are recorded. If diameters have to be measured at heights other than those indicated above, the height of the point of measurement has to be recorded. This is considered necessary to enable computation of stem volume and average length of pole timber rather than a total volume. The diameter is preferably taken with a diameter-tape, total heights are measured with a Suunto or Blume-Leiss hypsometer. Up to 3 m the heights of shrubs are estimated to the nearest 0.1 m using a collapsible meter.

Density count and biomass estimation of herbage

The grass and forb layer is sampled for density, species composition and weight inside of the tract:

1. Assessment of density
   Over a distance of two times 30 m it is being determined whether an iron rod stuck into the ground in 30 cm intervals is on covered or denuded ground. Sampling lines are at right angles to each other starting from the center of the tract.
2. Assessment of species composition
   Over a distance of 20 m each towards north and west, beginning from the center the 20 m distance-tape is stretched out and every 20 cm an iron rod is stuck into the ground. Each species of grass touching the rod is recorded.
3. Estimate of above-ground biomass
   For obtaining an estimate of the above-ground

biomass a square of 1 m side-length is thrown 20-30 times on the up-hill or down-hill sides (or north and south of the center). Grass and forbs within the square are clipped, dried if necessary, and weighed after separation of annual and perennial plants. The number of samples (20-30) to be taken will be determined on location depending on the homogeneity of the vegetation cover (Avery 1975, Boudet et Malacamp 1979).

Area estimation of cover types by line-survey

For obtaining an area adjustment factor of vegetation types estimated on large-scale aerial photo samples, changes of the vegetation cover types are recorded when walking along the perimeter of the sampling unit. For this purpose the 50 m-distance-type is laid out, starting at the point SE. Changes of cover density or cover composition are recorded by indicating the distance from point SE (zero). Setting the 400 m perimeter equal to 100, percentages of the cover types can be estimated (see fig. 5).

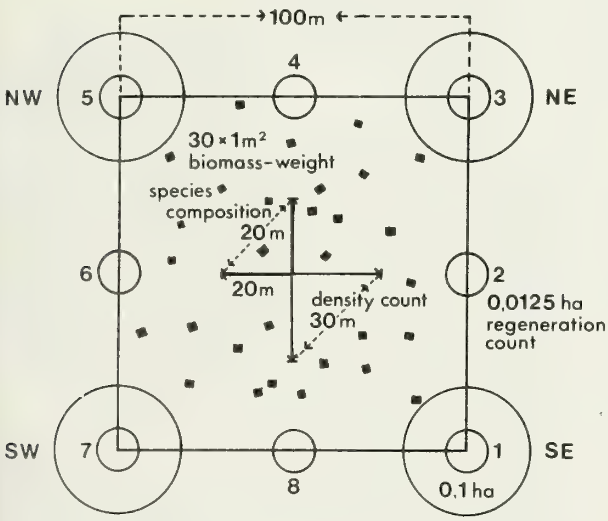


Figure 4.--Sampling unit (tract) proposed for vegetation cover assessment in the Sahel. Woody plants are counted and measured on circular plots, herbs and grasses evaluated within the 1 ha plot area.

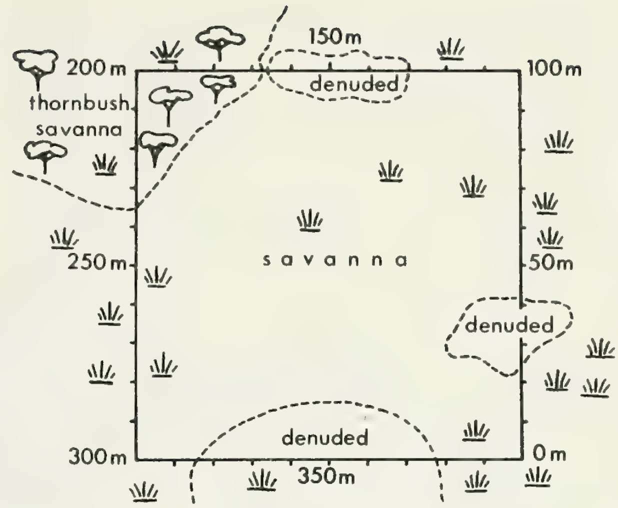


Figure 5.--Example of cover type estimation by line-survey along the perimeter of the sampling unit.

COST ESTIMATES

Cost estimate for large-scale aerial photography

Costs are given in Deutschmark (DM), conversion rate approx. DM 1,75 = US $ 1.-; 1980 prices are quoted for the camera equipment, rounded-up to nearest DM 100,-- including the added-value tax of presently 13 %. Rolls of films come in 30,5 m (100 ft.) length; 5 m fit into a 70-frame Hasselblad magazine, 10 m fill a 250-frame Canon magazine. About 1-5 frames/charge are used-up in camera checks and control photos.

<u>Equipment for 70 mm-photography</u>

2 Hasselblad EL 500 Automated	10.000,--	
6 magazines for 70 frames	6.000,--	
1 timer-intervalometer	800,--	
1 synchronizer	700,--	
20 spools	900,--	
2 camera housings	800,--	
2 clamps	600,--	
2 skylight filters	200,--	
total, base equipment (a)		20.000,--

<u>optional</u>

2 magazines for 500 frames	25.000,--	
1 back-up camera	5.000,--	
		30.000,--
total for large-area application (b)		50.000,--

Equipment for flight path tracking

1 Canon F1 35 mm camera	2.500,--	
2 wide-angle lenses	1.000,--	
2 250-frame magazines	1.000,--	
1 data control unit	2.500,--	
1 camera housing	300,--	
1 clamp	200,--	
total, 35 mm photo equipment (c)		7.500,--

Accessories

The cost of accessories such as batteries, charger, connecting cables, lightmeter, cassette recorder, pocket calculator, stop-watch etc. amount to approximately (d) 5.000,--

The total cost of photographic equipment for large-scale aerial photography amounts to (a+c+d) 32.500,--
or, with large magazines to (b+c+d) 62.500,--

which is close to US $ 21.500,-- or 36.000,-- respectively.

Film and processing costs per year

20 rolls (30m) Kodak Ektachrome 64, 70mm perforated	6.000,--	
20 rolls (30m) Ilford FP 4 35 mm	1.000,--	
10 rolls 70mm black/white film for repros	1.000,--	
photographic paper black/wh	1.500,--	
enlargements of color dias (prints)	2.000,--	
processing 20 rolls of Ektachrome 64	5.000,--	
processing 20 rolls of Ilford FP 4	1.000,--	
total, films and processing (e)		17.500,--

Aircraft rental

Assumptions: 10 missions per year, 3 hrs to reach the target area, 4 hrs operation; next day, 4 hrs operation, 3 hrs return to base. Total of

140 hrs at DM 200,--/hr	28.000,--	
indemnity to pilot DM 125,--/ day, on 10 occasions	2.500,--	
total, aircraft rental and pilot (f)		30.500,--

Equipment for sorting, filing and demonstration

The necessary equipment comprises luminous table, a numbering unit, frames for transparencies, envelopes for starage, trays, cassettes, projectors and a screen, dark room equipment, in total estimated at 10.000,--

Equipment for photo-interpretation and photogrammetric plotting

Depending on the amount of photographs to be interpretated and measured the equipment needed could consist of a bridge stereoscope with parallax bar or a second order stereoplotter with on-line data processing unit.

For the evaluation of aerial photos permanently acquired in the course of an inventory a sum of 200.000,-- must be invested.

Operation cost per year, per plot and per area unit

On the basis of 10 photo missions flown, the following costs are computed:

films and processing	17.500,--	
aircraft rental and pilot	30.500,--	
maintenance and repairs, 20 % write-off on photo-equipment	7.500,--	55.500,--
with large magazines	12.500,--	60.500,--

If, as assumed, 20 rolls of 70 mm color diapositive film are exposed, giving 6 charges of 5 m of film/roll, 120 magazines with 65 frames each can be loaded. Allowing for 10 % misses, the twin camera system can produce roughly 60 magazines per camera times 60 frames, i.e. 3600 stereo-photo plots, independent of scale, i.e. the cost per photo plot lies between DM 15,50 and DM 17,40 or US $ 9.- to US $ 10.-/photo-plot (interpretation and plotting not included).

To facilitate the conversion to area units the following relationships are given: At 100 m flying altitude and a focal length of 80 mm, the distance represented by a 70 mm photo with 55 mm of effective photo-format amounts to 100 times 55/80 = 68.75 m, or $(68.75)\ m^2$ by area. At 200 m flying altitude this distance doubles and the area increases by its square. With 10 % of endlap the effective photo-area is 137-13.7 = 122.3 m long by 137.0 m wide = 1.675 ha; 3600 frames cover 6030 hectares, hence the cost per hectare is DM 9,20 to DM 10,05 or US $ 5.25 to US $ 5.75/hectare at 1 : 2500 scale. These figures are in good agreement with those obtained by Aldred and Lowe (1978) in Alberta/ Canada.

Cost comparison of ground sampling vs. aerial photo sampling

To provide a basis of comparison of aerial photo and ground sampling costs, an estimate of equipment, personnel and operating costs is being attempted. The cost for 1 field crew leader has been deducted to offset the pay of the photo-operator.

Independent of the decision whether ground sampling units will be systematically or randomly distributed, considerable time will be required for locating the exact position of plot centers. Ideally, a special surveying crew should be charged with this job while two enumeration crews gather tree and range data. Assuming that a square tract of 100 m side length can be enumerated in one day, 2 field crews could measure 400 sampling units on 200 working days/year. Crews consist of a crew leader, a driver and 3 assistants. They dispose of one cross-country vehicle equipped with camping gear for 5 persons, field instruments and a portable radio, with a total value of DM 50.000,--; service-life of cars and field equipment has been set at 5 years.

For an inventory cycle of 5 years during which 2000 field plots are enumerated the following costs would be incurred:

- cross country vehicles (3)	DM 120.000,--
camping gear (15 sets)	DM 15.000,--
field instruments	DM 8.000,--
radios (3)	DM 6.000,--
gasoline etc.	DM 45.000,--
salaries (13 persons)	DM 210.000,--
total field sampling	DM 404.000,--

Hence, the cost of surveying and enumerating one field sampling unit is DM 202,--/unit. Under the same premises the following calculations are made for aerial photography of 18.000 (5 years with 3600 photos) large-scale stereo-photo-plots:

- photographic equipment	DM 60.000,--
documentation, storage	DM 10.000,--
photogrammetric equipment	DM 200.000,--
aircraft rental	DM 150.000,--
films and processing	DM 100.000,--
	DM 520.000,--

The cost for photographing and photogrammetric interpretation of an aerial photo-plot amounts to DM 29,--/photo-plot. The order of magnitude of the relationship of aerial to ground sampling of 1 : 7 is in line with the experience reported by Aldred and Lowe 1978 and Rhody (1980b).

This relation could probably be improved in favor of aerial photo-sampling, since photographing 3600 stereo photo-pairs takes actually not more than 10 - 20 days of operation. Under these conditions service life of photographic and photogrammetric equipment could be expected to last 10 years or, if the equipment is used more intensively, the per unit cost would drop. Of the cost of DM 29,--/photo-plot, DM 11,-- are caused by the write-off on photogrammetric equipment.

Cochran (1963) explained the statistical background of regression or double sampling with stratification. The optimum allocation of the total number of sample plots to aerial and ground plots as a function of the coefficient of correlation between photo and ground measured variables and the cost quotient c_p/c_g has been described by Loetsch and Haller (1964, P. 235) and by Bonner and Aldred (1974, P. 270).

Assuming a coefficient of variation (cv) of utilizable tree volume within a stratum of 40 % (the stratum area is known from small-scale aerial photography), a correlation coefficient (r) of 0.8 between photo and ground-estimated volume and a cost fraction c_p/c_g of 1 : 10 for aerial vs. ground sampling costs, the total number (m) of photo samples required to attain a standard error e of 2.5 % at the 95 % probability level (t = 1.96) would be

$$m = \left(\frac{cv \cdot 1.96}{e}\right)^2 = \left(\frac{40 \cdot 1.96}{2.5}\right)^2 = 984.$$

Using

$$f = \frac{n}{m} = \sqrt{\frac{(1 - r^2)\, c_p}{r^2\, c_g}}, \quad f = \sqrt{\frac{0.36}{(0.64)10}} = 0.24,$$

the optimum allocation in this case would be that 24 % or n= 236 of the total number of 984 samples are ground samples and 748 are photo-samples. At the above costs this means DM 70.000,-- vs. 199.000,-- or DM 129.000,-- in favor of the t o-phase design.

PRELIMINARY RESULTS

The investigations carried out in Upper Volta with large-scale aerial photo equipment had several objectives:

1) To find out whether the equipment would function and could be operated under the climatic conditions of a semi-arid region.
2) To ascertain that the photography obtained is of such quality that it could be used in partial replacement of field plots for aerial photo-sampling.

The first photos were flown in March 1978, practically in the middle of the dry season. At this time of the year dust storms are quite frequent and visibility becomes so low that small planes remain grounded. Even several days after the storm the air is still hazy. The best time for photo-missions is from 9.00 to 11.00 hrs in the morning and from 14.30 to 16.30 hrs in the afternoon. Before or after, shadows are very long and crown perimeters are difficult to localize. Between these periods, thermic up-draft is so strong that it is nearly impossible to keep the aircraft stable. During and after the rainy season the air is very clean and very brilliant photos are obtained. Species identification is easier on these photos because crown shapes and structures are seen more distinctly and the color of foliage is an additional aid in identification. However, in the tall grass and under the canopy of trees small trees and bushes are not discovered such that counting of woody plants is less accurate. In the afternoon thunderstorms are frequent from Juli to September. In general, aerial photographs should be taken towards the end of the rainy season, when weather conditions are nearly stable, but areas bare because of erosion can be well distinguished from over-grazed pastures.-The concept of two-phase sampling rests essentially on the condition that part of the aerial photo-samples are visited and enumerated on the ground and that the correlation between photo- and field measured variables is high. It was found that crown diameter and total height are highly correlated to dbh (r^2=0.72), hence, volume estimation by multiple linear regression will be feasible.

Further objectives of the study were to work out indicators of desertification risks. Figure 6 shows a line drawing made from enlarged black and white prints of an area 10 km east of Djibo (14°5'N and 1°35'W). After field sampling in the fall of 1978, 80 ha had been reforested in the wet season of 1979 (northwestern corner), encircled by a trail, for guards. Blank areas are void of vegetation, horizontally hatched areas have a contiguous grass cover, but few old trees and very little bushes or natural regeneration. Vertically hatched areas are in good condition. The southern part is crossed by cattle trails running NE/SW between a water hole further to the SW and pastures in the NE.

Circles indicate the position of 8 circular, 0.1 ha sample plots, spaced 100 m apart;

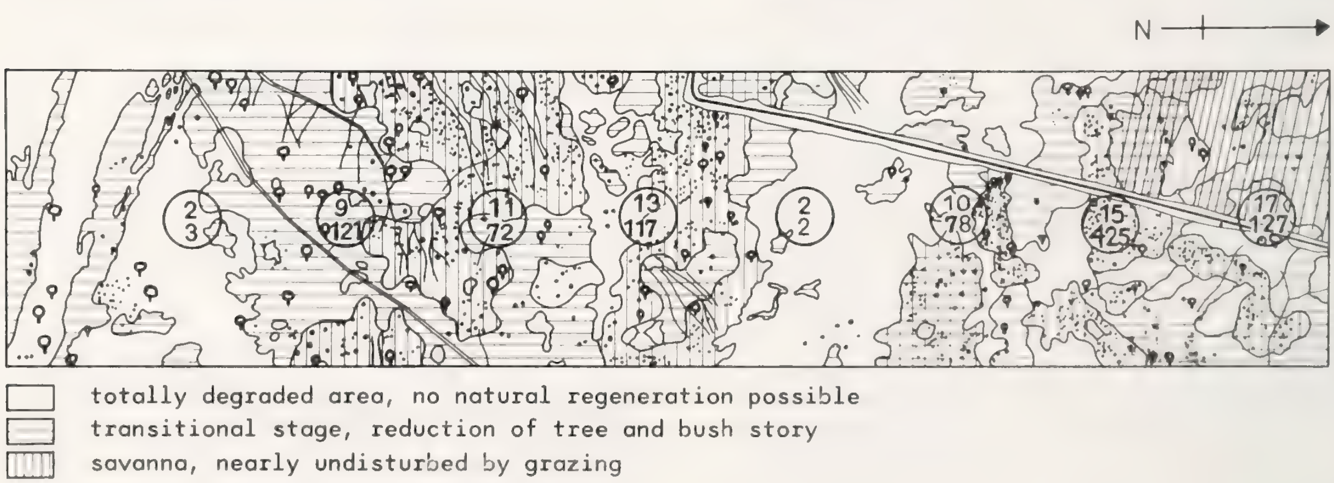


Figure 6.--Classification of desertification processes

figures indicate the number of species and woody plants counted on that plot. A stratification of the area by transect sampling indicated 32 % bare ground, 50 % grassland and 18 % of densely covered thornbush savanna. Similar maps can be drawn up for larger areas as a base for management planning.

The section shown covers 16 ha with an average of 118 plants from 10 species per plot, coefficients of variation are 133 % for the number of plants/plot and 56 % for the number of species. Stratified sampling using the three classes as indicated above, reduces the coefficients of variation to about 25 % for frequencies of individuals and species within strata. If an inventory of vegetation resources is conducted in this area a key for the stratification of vegetation types must be worked out, possibly based on the concept developed by Toutain and de Wispelaere (1978) for the classification of pastures. Processes of desertification can be recognized by species composition, density per unit of area and by height distribution. A cluster of twenty-one 0.1 ha sample plots indicated a growing stock of 818 plants from 24 species per hectare. The height distribution reveals, however, that 83 % of all woody plants are not higher than 1.0 m, 12.1 % are between 1.0 m and 2.0 m high and only 4.9 % exceed 2.0 m, thus having reached the stratum of established plants capable of procucing increment that is not continuously grazed or browsed off (see also tables 1 and 2).

Table 1.--No. of observations (x), means ($\bar{x}$), standard deviations (s) and coefficients of variation (s%) for number of plants and species for 8 (5) 0.1 ha sample plots near Djibo

8 0.1 ha plots

variable	no. of plants	no. of species
x	944	22
$\bar{x}$	118,0	9,9
s	133,5	5,5
s%	113,1	55,8

5 0.1 ha plots

variable	no. of plants	no. of species
x	514	22
$\bar{x}$	102,8	12,0
s	25,7	3,2
s%	25,0	26,4

Table 2.--Height distribution of 1717 woody plants of 21 circular 0.1 ha sample plots

	height in cm				
variable	0-100	110-200	210-300	310-400	410 +
number	1424	207	33	16	37
percent	83.0	12.1	1.9	0.9	2.1

CONCLUSIONS AND SUMMARY

Population pressure and the resulting over-exploitation of range and forest resources have led to far-spread desertification in the Sahel of West-Africa.

Because of the extent of the Sahel, its inaccessibility and the low commercial value of savanna and rangelands, a cost-efficient inventory design must be used for the assessment of the state and evolution of the natural, renewable resources. A twin-camera system for obtaining large-scale aerial photography has been tested for investigating its potential use in a two-phase sampling design with predominantly aerial photo-sampling and a marked reduction of the number of field plots.

The camera system, based on the concept of fixed-base stereo-photography, consists of two automated Hasselblad EL 500 cameras and a motorized 35 mm camera for flightpath tracking. The scale of each photo-pair can be calculated by means of the fixed base, eliminating the need for ground truth points. Stereo-pairs of 70 mm color slides are photogrammetrically evaluated with a modified Zeiss Planitop F2 stereo-plotter with on-line data processing. Tree and bush counts on photos of 1 : 2500 scale were 90 % correct, however, only groups of species could be identified. The photo-measured variables, total height and crown diameter, are highly correlated ($r^2 = 0.72$) to

ground-measured dbh, indicating the feasibility of volume estimation by multiple linear regression models.

In addition to aerial photo-sampling of forest and range resources and desertification processes this camera system can be used for the observation and monitoring of sudden events of localized extent. Up to 200 stereo-pairs of selected sites can be obtained during one hour of flight for about DM 15/pair. Mobility, simplicity of operation, use of standard films and processing techniques and of light, fixed-wing aircraft such as the Cessna 150/170, available on a rental basis from most aeroclubs, indicate the universal potential of this camera combination for the assessment of the state and changes of natural, renewable resources in arid regions of difficult access at reasonable cost.

CONCLUSIONES Y SOMARIO

Aplicación de la fotografía aérea a gran escala para inventario de los recursos naturales renovables en el Sahel de la Alta Volta

El aumento demográfico, y de ahí la sobreexplotación de los recursos forestales y pastoriles, produjo y sigue produciendo la desertificación en el Sahel del Africa Occidental. Para detener este peligroso desarrollo, se deben introducir sistemas conjuntos de la agronomía y silvicultury (agroforestry); sin embargo, antes de que se pueda formular una politica a largo plazo de la utilización racional de los terrenos, se debe efectuar un inventario del estado y de la evolución de los recursos, así como el cuidado y conservación de éllos. Se debe tomar en cuenta así mismo, la superficie, la inaccesibilidad de la región y el bajo valor de estos recursos a nivel comercial para que el método estadístico aplicado sea tanto efectivo como económico.

En el proyecto bilateral de ayuda técnica prestada por la Alemania Federal para la Alta Volta, se utilizó un sistema de camaras gemelas para la toma de fotos aéreas a gran escala, con el objeto de verificar su aplicación en un muestreo de dos fases, es decir muestreo en fotografías aéreas y en un número reducido de parcelas de terreno. Mediante la aplicación de las fotografías aéreas de parcelas de muestreo, se esperan también ventajas considerables para un control permanente del desarrollo de los recursos en regiones de difícil acceso por vía terrestre. Este sistema de camaras, elaborado por B. Rhody, se basa en el principio de la fotografía estereoscópica a base fija que permite calcular la escala de un par de fotos estereoscópicas, eliminando la necesidad de poner puntos de referencia en el terreno. El sistema consiste en dos camaras automáticas Hasselblad EL 500 para peliculas de format 70 mm y otra motorizada de 35 mm para documentar con fotos contínuas la banda de vuelo. El valor del equipo fotográfico es de aproximadamente US $ 15,000.

Las diapositivas en color de 70 mm se evalúan utilizando un estereoscopio modificado tipo Zeiss Planitop F2 con medición de variables como altura de los arboles y dia metro de la cima en las fotos, para la determinación del volumen de los arboles de muestreo por regresión multiple. A una escala de 1 : 2500, la enumeración de los arboles y arbustos produjo resultados correctos, en el 90 % de los casos, mediante fotos de la estación de sequía. La determinación de las especies de los arboles es difícil aún con fotos de la temporada de lluvias, solo grupos de especies, por ejemplo las Acacias, se pueden distinguir perfectamente de los arbustos, no-espinosos. Para obtener resultados exactos, la escala de las fotos obtenidas en el vuelo debe ser aumentada a 1 : 1200. Fuera de la densidad de las plantas, no es posible obtener otras características preponderantes del estado de los pastos. Como las especies de los arboles estan determinadas por el sitio, la calidad del sitio es un buen determinante para la composición de especies de las hierbas y capa de arbustos.

Por otro lado este muestreo fotográfico de camaras combinadas de pastos y bosques podría utilizarse también para la observación y control del desarrollo urbano, para la evaluación de catástrofes naturales como fuego, inundaciones, huracanes, concentración de animales de pastoreo cerca de manantiales profundos; también exito o fracaso en nuevas plantaciones de arboles etc. Durante una hora de vuelo se puede tomar 200 pares de estereofotos de sitios selectos a un costo de DM 15/par. En síntesis, este sistema, - debido a su movilidad, simplicidad de operación, uso de peliculas estandard y de avionetas normales alquiladas del tipo Cessna 150/170, - parece bién apropriado tanto para el muestreo aéreo como para vuelos de reconocimiento con fotodocumentación en regiones aridas de difićil acceso a un cuesto acceptable.

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Vegetation Inventories and Interpretation of Environmental Variables for Resource Management: Grand Canyon National Park, A Case Study[1]

David A. Mouat[2] and R. Roy Johnson[3]

Abstract.--Vegetation is useful in resource management because it can be considered as an indicator of the environment. Vegetation inventory techniques include conventional methods as well as those involving terrain feature-vegetation relationships. The Grand Canyon is used as a case study due to its environmental diversity and resource management problems.

INTRODUCTION

For too long, resource managers have dealt with "brushfire" problems with a paucity of environmental information. The "solutions" to these problems, although seemingly effective on a short term basis, often result in additional long term problems of even greater magnitude. An ecologically sound resource inventory emphasizing vegetation is essential for use by the resource manager to eliminate these problems. Vegetation is being considered because it:

a. is relatively stable,
b. is relatively simple to map, requiring minimal special equipment,
c. can be efficiently mapped over large areas,
d. can be used by the resource manager as an indicator of the specific environment.

The Grand Canyon poses a unique challenge for the inventory specialist. The geologic and terrain diversity is matched by a myriad of vegetation types, each one reflecting an integration of the total environment. On account of the arid and semiarid climate as well as the lack of accessibility of much of the terrain, special techniques must be developed to inventory, classify, and map the vegetation.

CONSIDERATIONS IN VEGETATION INVENTORY METHODOLOGY

Vegetation mapping has progressed considerably in the middle of the 20th century with the assistance of remote sensing technology. The use of black and white aerial photography provided a perspective in estimating cover, interpretation of general types, and delineation of type boundaries on an easily convertible mapping base. The use of stereoscopes, photogrammetric techniques and other

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equipment has greatly improved the mapping procedure (Mouat and Johnson, 1978).

Recently, developments in film-filter combinations, sensing systems, sampling techniques, and analytical procedures have added a new dimension to vegetation mapping. Color and color infrared films with the appropriate filter combinations permit a much wider variety of vegetation discrimination than black and white photography. Color infrared photography is particularly well-suited to vegetation discrimination as it is in the near infrared portion of the spectrum that vegetation is most responsive. In areas of sparse vegetative cover, however, color infrared may be less useful than natural color in discriminating vegetation types since the soil surface dominates the spectral return. Soils are often more readily discriminated by the use of natural color photography.

Satellite sensing systems, particularly the Landsat satellites, have provided vegetation mappers with an important technique for mapping vegetation resources over extensive regions, for monitoring phenological changes by taking advantage of Landsat's eighteen day repetitive cycle (nine days with two Landsats), and for analysis through the satellites radiometric precision. Numerous projects have employed Landsat for inventory and analysis of vegetation resources (e.g., Hutchinson, 1978 and Dunford, Mouat and Slaymaker, 1980).

Through whatever technique is used in the mapping process, vegetation inventory begins with an understanding of intended use and the design and development of an appropriate classification system. This system must fit the factors of vegetation which are pertinent to any of the objectives for which the vegetation map is to be produced.

In mapping vegetation for resource management, especially through remote sensing techniques, a classification system that is flexible yet readily comprehensible by resource managers is essential. The classification system which we have developed and have used in several projects follows Brown, Lowe, and Pase (1979). It is a digitized, computer-compatible system for natural vegetation in North America, following a hierarchical format and is based on climate, ecology and evolution. We have added levels which take into account variation in relative abundance and spatial distribution of characteristic and associated species within a type.

A hierarchical legend system is of critical importance in a vegetation classification as it allows for aggregation of units at smaller scales and disaggregation at larger scales of mapping intensity. In areas of varied accessibility and equally varied vegetation diversity, a system which allows for both detailed as well as general descriptions is very desirable (Mouat et al., 1979).

Vegetation type descriptions are highly important in inventory. The description is often based on two considerations: the type of information desired in the maps, and the constraints on mapping accuracy imposed by the image analysis of the proposed types. Mapping unit descriptions contain three categories of information which serve as a basis for classification of vegetation, physiognomy, floristics and distribution (Küchler, 1973, 1977). The vegetation type descriptions are based upon a summary of species occurrence as identified through field sampling for each type.

The amount of information provided in the description for a large scale map is a logical and necessary extension of the legends provided for smaller scale vegetation maps. As attention is focused on smaller areas for research or management purposes, the amount of information required to meet the needs for which the map is designed increases. At small scales, purely structural information may be sufficient for the purpose of the map. However, at large scales, when relatively subtle differences may distinguish associations, information of several kinds is necessary to adequately characterize the association. Vegetation type descriptions should also include information on the relative abundance of component species within type variation, and distribution. The thoroughness of the association descriptions (which depend upon adequate field sampling) determines the final utility of the vegetation map, and to a large extent is independent of the classification system used (Mouat et al., 1979).

The use of remote sensing techniques for mapping, as mentioned previously, involves both traditional and state-of-the-art methods. While these techniques have been reported extensively in the literature, vegetation mapping procedures in arid regions often involve modified techniques. Mouat and Treadwell (1978) and Mouat et al. (in press, 1980) have reported on the importance of establishing image-subject relationships involving vegetation and arid regions. Natural color photography is often preferred over color infrared for several reasons. It is less expensive, more reliable, more easily replicated and usually more timely. Most importantly, it gives a more readily comprehensible portrayal of the surface parent materials and soils. Color differentiation in arid and semiarid soils is often quite striking. The image analyst and ecologist must relate image characteristics - especially the color of the arid soil to its correlative vegetation association.

Digital analysis of Landsat data for the analysis of detailed vegetation types has met with very limited success. The integration of digital terrain data with Landsat data has improved classification techniques.

Inventory specialists are continually searching for ways to improve mapping accuracy and efficiency. In some instances, the goal is to map finer levels of detail. In others, it may be to map similar

levels of detail as can be produced for areas with ready access to areas which are essentially inaccessible. The Grand Canyon affords ample opportunity for the latter! An area of arid and semiarid habitat is combined with terrain inaccessibility and extreme relief to create a challenge to the arid lands vegetation mapper. A lack of ground control renders the traditional techniques useless. It also precludes standard Landsat digital classification on account of a lack of training and test site definition. Another technique is clearly called for The input being used in the Grand Canyon Vegetation Mapping Project is the terrain correlate. Mouat (1972, 1974a, 1974b; Mouat and Johnson, 1978) has hypothesized that vegetation correlates well with "certain" terrain variables. If a positive relationship can be found to exist between vegetation and a set of interpretable terrain variables then by interpreting terrain features and combining that information with image information, the vegetation analyst and mapper should be able to infer vegetation.

INTERPRETATION OF ENVIRONMENTAL VARIABLES FOR RESOURCE MANAGEMENT

In arid and semiarid regions, especially those with considerable ranges in environmental conditions, vegetation can be highly correlated with a number of environmental variables and may, in fact, be used to reflect or mirror the effective environment. The implications of this hypothesis center on the importance of vegetation as a key to the environment.

Because vegetation is so readily mappable, the knowledge of its environmental indicators would be of considerable use to the resource manager who needs to make decisions on a large number of environmental factors but does not have the resources to undertake individual comprehensive inventories of these factors. Considerable effort must still be expended in order to arrive at the appropriate environmental indication.

Figure 1 illustrates the relationship among

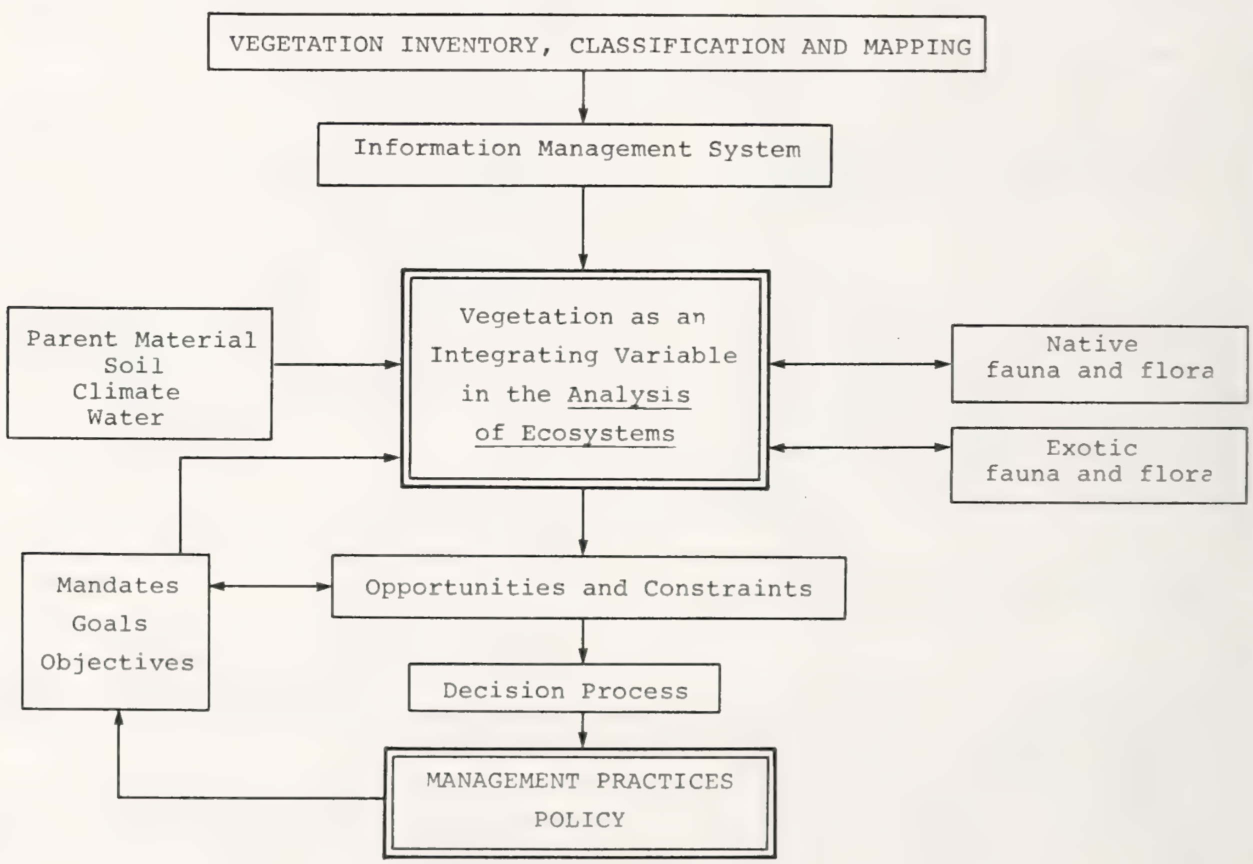

Figure 1. The role of vegetation in resource management.

the components of a hypothetical model of the role of vegetation in resource management. It is important that the resource manager understand the role of vegetation in indicating the environment.

Regarding the importance of vegetation as a synthesis of factors in explaining effective environment, Scott (1974) states that natural plant communities are the best indicators of the physical environment. As an example, he explains that a wet to dry sequence along some moisture factor complex may be indicated by the range of species in a study area. The vegetation of the area might give an even better indication of this continuum.

That vegetation is strongly related to environmental factors has been stated for some time. Billings (1952) indicated the complex interactions between environment and plants (vegetative cover) through time. His "complex" included radiation, temperature, moisture, topography, parent material, soil, other plants, animals and man. Major (1951) was a bit more specific in stating that vegetation (v) is a function (f) of soils (s), climate (c), animals (a), and flora (fl) or:

$$v = f(s + c + a + fl)$$

Daubenmire (1968) stated that plant communities are the products of interaction between two phenomena: the differences in the environmental tolerances (or ecologic amplitudes) of the various taxa which comprise the flora and the heterogeneity of the environment. Thus, we can seemingly draw inferences either from the standpoint of the vegetation or from the environment toward the others. The discreteness of vegetation can best be illustrated in areas such as the Grand Canyon where there are sudden discontinuities in the environment such as changes in soil, parent material, elevation, or slope aspect. Certainly, in these instances, a continuum viewpoint regarding vegetation types can scarcely be said to be entirely valid (Barbour, et al., 1980). In arid and semiarid regions, subtler discontinuities in the environment might result in critical moisture barriers for plants being crossed and the same result might occur (that is, vegetation types changing rather profoundly).

deLaubenfels (1975) also states that vegetation is an integration of all the factors of the natural environment. Every vegetation type has a certain range of habitat. Some types occur almost globally while others are confined to a very restricted set of conditions which may be realized only within a small area.

The specific relations between vegetation and climate is scale dependent. At global scales vegetation mirrors climate, at microscales it is an indication of more complex interactions and includes succession, microclimate, etc. The forces which actually affect vegetation are limited in number and nature by the constitution of the component flora.

Numerous techniques can be used to understand the relationships that exist between vegetation and environment. Direct gradient analysis, for example, begins with known environmental variations. Floristic variation is then correlated to find out to what extent the known variation of environment coincides with the floristic variation encountered. As a result, this analysis contributes greatly to the elucidation of the underlying causes of plant and community distribution. Indirect gradient analysis examines the patterns formed by the vegetation itself. An attempt is made to interpret the floristic patterns in terms of environmental relations (from Mueller-Dombois and Ellenberg, 1974).

Whichever technique is used in analyzing the environment-vegetation relationship, the investigator must understand the ecology of the area in considerable detail first. The site indicator value of species groups or communities comes from knowing the ecological effect of site factors such as topography, water table relations and soil characteristics. With a well-established site indicator value for vegetation types, site potential or the productive capacity of habitats can be established (Mueller-Dombois and Ellenberg, 1974).

Terrain factors and their management implications are important components of site evaluations. Terrain relates to numerous resource management considerations. There are a number of ways in which vegetation is important in the evaluation of terrain. It is an important key to the recognition of terrain types particularly when they are viewed from the air. It is an attribute in the definition of terrain types. The single most important factor in the relationship between terrain and vegetation is probably the effect of the ground configuration in determining soil moisture conditions (Mitchell, 1973). Therefore, vegetation is an especially valuable index of terrain in areas where soil moisture variations cross limits which are critical to plant growth as in semiarid lands.

The vegetation will reveal the finest variations in site qualities and, as such, is used in determining a wide range of resource use considerations including land use planning, agriculture, forestry, wildlife management, range management, and mineral prospecting. The nature of the vegetation map and classification is critical. The site evaluation potential for physiognomically-based classifications and maps is low as the correlations are low among structure and environmental attributes. However, floristically-based classifications may have a pronounced correlation (and hence utility) with those same attributes.

The vegetation map and classification produced for Grand Canyon National Park has been designed for maximum ease of understanding and utility. The resource manager must understand the relationships involved in order to maximize the utility of the vegetation map as an effective management tool.

THE GRAND CANYON AND RESOURCE MANAGEMENT

The Grand Canyon of the Colorado River, located in northwest Arizona, one of the "seven natural wonders of the world", was carved by the Colorado River in conjunction with other natural forces. The three billion year old Precambrian schist and granite at its bottom are among the oldest known rocks on earth (Breed and Roat, 1967). Due to the immensity of the Canyon (277 miles-446 km long, 1 mile-1.6 km deep and approximately 15 miles-24 km across at its width) a tremendous diversity in plant and animal communities occurs within the Canyon and along its rims.

It was here that Merriam (1890), impressed by the vast array of biological communities ranging from the top of the San Francisco Peaks (12,670 ft.-3,862 m) to the bottom of the Canyon, formulated his widely used Life Zone system. The Canyon is especially known for its varied lithology and unique geologic features. The vast ranges in elevation and associated topographic relief result in a corresponding diversity of temperature, precipitation and the aforementioned array of plant and animal communities.

The Colorado River, the major river draining the southwest United States, originates in alpine areas of the Front Range of the Rocky Mountains in the vicinity of Rocky Mountain National Park and flows approximately 1400 miles (2,253 km) to the Gulf of Lower California (Johnson, 1979). Even though these headwaters originate in a mesic environment, the region is generally arid or semiarid. Lower elevations commonly receive less than 10 inches (25 cm) of precipitation annually with less than five inches (13 cm) in drier areas. July temperatures average greater than 80°F (26°C) (90°F-32°C-plus in many localities) and summer temperatures commonly exceed 110°F (43°C) resulting in evaporation rates in excess of 100 inches (254 cm) annually through much of the lowlands.

It is along the 277 mile (446 km) stretch of the Colorado River flowing through Grand Canyon National Park that the montane ecosystems of the Colorado Plateau give way to the habitats of the Basin and Range Province (Hunt, 1974) which characterize the semiarid and arid deserts of the Southwest. Elevations in the Park extend from above 9,200 feet (2804 m) to less than 1,200 feet (366 m) with annual precipitation ranging from 30 inches (76 cm), much in the form of snow (annual snowfall commonly exceeds 200 inches) to less than 10 inches (25 cm) in the lower, arid areas in the bottom of the Canyon. Temperatures range from summer highs here of greater than 115°F (46°C) to winter lows of less than 25°F below zero (-31°C) on mountain peaks. Major vegetation types at higher elevations consist of boreal forests supporting such tree species as Engelmann spruce *(Picea engelmanni)*, white fir *(Abies concolor)*, aspen *(Populus tremuloides)*, and Ponderosa Pine *(Pinus ponderosa)*. Woodland types at intermediate elevations consist largely of pinyon *(Pinus edulis)*, Junipers *(Juniperus monosperma* and *J. osteosperma)* and oaks *(Quercus gambelii, Q. undulata* and *Q. turbinella)*with large areas of sagebrush *(Artemisia tridentata, A. nova*, etc.) and/or saltbush *Atriplex canescens)*, scattered rabbitbush *(Chrysothamnus spp.)* and other species. Arid areas of less than 12 inches (30 cm) annual precipitation support blackbrush *(Coleogyne ramosissima)*, generally at elevations between 4,000 to 5,000 feet (1219 to 1524 m) and desert scrub at lower elevations dominated by such species as white brittlebush *(Encelia farinosa)*, prickly pear *(Opuntia spp.)* and creosotebush *(Larrea divaricata)* at the lowest elevations.

This plethora of habitat types supports an equally varied array of wildlife. Thus, an inventory of the vegetation, wildlife, and other natural resources of the Park in addition to being of critical importance to the management of the Park's resources is also of major importance to managers and scientists throughout the southwestern United States and northern Mexico. National parks have been established to allow the continuity of natural processes and the maintenance of resultant native ecosystems. Many of the management schemes conducted on lands managed by other resource agencies are not practiced in Grand Canyon National Park. This includes lumbering, hunting and grazing. Thus, the relatively undisturbed natural resources of Grand Canyon National Park represent a control area with which these management practices on non-Park Service lands can be compared. Few would question the fact that an activity such as lumbering is an important resource management function. However, are the ways in which we conduct lumbering the most effective methods? Are senescent forests really "unhealthy", as is often claimed, or are processes associated with these "overly mature" forests of critical importance to the natural ecosystems of a region. Similar questions can be asked of current methods of hunting, cattle grazing, stocking of game fish, and other practices not conducted on most park lands. Some practices, such as hunting or even the control of exotics (such as burros), are being strongly questioned for either National Park Service lands or public lands in general.

Although a person of no less importance than Aldo Leopold (1933) clearly distinguished the difference between game and wildlife management almost 50 years ago, many resource managers still confuse the broad activity of "wildlife management" with the much more limited "game management" (Carothers and Johnson, 1975). The National Park Service is equally concerned with management of native game animals and nongame species. Thus, resource managers at Grand Canyon National Park are concerned with not only maintaining natural populations of mule deer *(Odocoileus hemionus)* and bighorn sheep *(Ovis canadensis)* but also protection and maintainance of healthy populations of mountain lion *(Felis concolor)*, coyotes *(Canis latrans)* or even whiptail lizards *(Cnemidophorus spp.)* and cactus mice *(Peromyscus eremicus)*. Thus, the National

Park Service is attempting to use the most up-to-date techniques in an attempt to conduct the best possible practices in management of natural communities. Since the Park Service has been entrusted by Congress to preserve these resources for posterity, a necessary part of these management activities consists of an accurate inventory of natural resources before they are so altered by human activities that the natural condition is not known.

VEGETATION AND WILDLIFE MANAGEMENT: THE GRAND CANYON BURRO CONTROVERSY

An important use of vegetation inventories by resource managers is in the field of wildlife management. An outstanding example of a critical wildlife management problem in an arid environment which has arisen in the absence of adequate vegetation inventory information has been the impacts of feral asses *(Equus asinus)*, or burros, on vegetation and associated wildlife in the arid southwestern United States.

The efforts to maintain National Park Service lands in a "natural" (pre-European man) condition have been most severely threatened by domestic and feral livestock. Environmental damages from several of these domestic animal species, especially under arid conditions, have been well documented.

Grand Canyon National Park is typical of several Parks in the Southwestern United States in which burros have been threatening natural ecosystems. The Grand Canyon has become the focal point of a bitter battle to determine the fate of the burros. Arguments supporting control or eradication of the burros center on damage to the vegetation of the Park. Burros (1) compete with native wildlife for water, forage, and space; (2) forage selectively and, thereby, may endanger some species of plants; (3) leave trails and dust wallows barren, resulting in (a) less ground cover which can lead to increased erosion, (b) compacted soil thus reducing use by plants and animals; (4) foul water holes for other wildlife and hikers; (5) desecrate campsites with their trampling and the elimination of their wastes; (6) create aesthetically less pleasing landscapes.

Arguments for burro retention center on their aesthetic qualities as "tourist attractions" and on their having as much right to be there as do other forms of wildlife even though those other species are indigenous.

This paper will only summarize the historical perspective of the burro and the arguments for its retention or removal from within the Park. The importance of plant and animal inventories to determine populations in arid terrain can not be understated and will form the underlying basis for the discussion. The reader is referred to other articles (e.g., Carothers, et al., 1976) for a more detailed historical perspective.

In 1978, the Grand Canyon burro herd was estimated at approximately 300 individuals through the use of the Lincoln Index techniques (mark-recount) (Ohmart, et al., 1978). Today the herd is estimated at 350 animals or more than 3% of the burro population of the western United States as estimated by Woodward (1976). Nearly all of these burros live in arid and semi-arid habitats. These habitats extend from creosotebush *(Larrea divaricata)*, saltbush *(Atriplex spp.)*, and other low elevation desert types, such as are found in western Arizona, through the pinyon-juniper association as occurs in Bandelier National Monument, New Mexico. The severity of damage to vegetation, and consequently wildlife, in these fragile arid ecosystems needs to be addressed in conjunction with the importance of understanding the vegetation resources of these areas.

Natural resource managers, especially within the National Park Service, who have been faced with the burro dilemma, have tried to sort out the factors which caused the problem. The Wild Horse and Burro Act (Public Law 92-195) makes the killing of burros illegal on most public land. Thus, managers who were aware of burro damage on land under the jurisdiction of U.S. government agencies such as the Bureau of Land Management and the Forest Service were helpless to take preventative action until the alternative burro round-ups and "adopt-a-burro" programs were developed to remove burros from these areas. While the National Park Service was expressly exempted from the Act, public opinion (expressed to Congress, the Secretary of the Interior, and even the White House) caused resource managers in the National Parks to cease efforts to control burros. As a result, an increase occurred in the damage done to vegetation and soils in those fragile arid ecosystems.

In the earlier days of the Park Service, the philosophy of best management was "least management". The "problem" of the burros or, for that matter, any non-native animal encountered in a Park was answered by attempts at removal. Little research was done, and there wasn't any need for extensive (and expensive) "before and after" inventories to evaluate the damage from the animals. In fact, in the Grand Canyon, 2,860 feral asses (or burros) were removed between 1924 and 1969 at which time the effort ceased due to public pressure.

Resistance to killing burros has gained since that time. Despite our knowledge to the contrary, some people claim little environmental damage from burros. Moehlman (1972), for example, in a widely read article in National Geographic denied noticeable damage by the feral ass by stating..."Contrary to a widely held belief, the burros I observed did not strip the land, foul water holes or endanger other animals... Although heavy browsing occurred within a mile of water, my first appraisal of vegetation data indicates (sic) that plants on

which burros feed do not suffer severely." Our photographic evidence from Death Valley as well as work there by Douglas and Norment (1977) and that of other investigators (Bennett et al., in press) in Grand Canyon National Park show that these conclusions were not valid. Additional information regarding burro impacts on native ecosystems may be obtained from Wauer and Dennis (in press) and Woodward (1976).

The Grand Canyon Burro Management Plan which proposed to eliminate burros from certain portions of the Grand Canyon (Department of Interior, 1979) has received the support of the Arizona Wildlife Federation, various Audubon Society groups, the Desert Bighorn Sheep Society, and nearly every resource management group asked for comments. Still, organized groups supported by public sentiment have maneuvered the issue into litigation by federal courts.

In retrospect, if certain studies and documentations of burro damage had been carried out, the severity of the current resource management problem would have been lessened. More thorough studies should have been undertaken on the damage to native plants and animals along with earlier control programs. Sample plots in areas with burros have been compared to similar plots in areas where no burros occur. In addition, plots have been studied and analyzed for vegetational differences before and after burros were removed. Finally and foremost, vegetation inventories have now been completed which demonstrate statistically and conclusively the extent of damage which has resulted from leaving these exotic burros in the native Grand Canyon ecosystem. The inventory is greatly improving the efficiency and accuracy of National Park Service attempts to address such issues as:

1) the amount of suitable arid habitat available to the burros;
2) the amount of this habitat that is inhabited by burros,
3) the condition of vegetation and wildlife in areas inhabited by burros compared to those areas devoid of burros.

SUMMARY

No longer can the philosophy that "the best management is the least management" or "the best research is the least research" be followed. We cannot know if degradation is occurring today or will occur tomorrow if we don't understand our current resources. With adequate and periodic resource inventory information we can understand the changes that are taking place in our resource base. If we are to adequately meet resource management problems of the future we must use remote sensing and all other scientific tools available to conduct thorough resource inventories today.

Vegetation resource inventories can provide an appropriate answer to the problems faced by arid lands resource managers. These inventories can be readily and efficiently accomplished and if they are employed in a rational decision-making framework can provide answers to a number of environmentally-related issues.

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INVENTARIO DE VEGETACION E INTERPRETACION DE VARIABLES DEL MEDIO AMBIENTE PARA MANEJO DE LOS RECURSOS: GRAND CANYON NATIONAL PARK, UN ESTUDIO DE CASO

Durante mucho tiempo los administradores de recursos naturales han intentado tratar con los problemas mas urgentes frente a una escasez de informacion acerca del medio ambiente. Las supuestas soluciones, aparentemente exitosas a corto plazo, con frecuencia han resultado en la creación de problemas adicionales a largo plazo y de mayor magnitud. Para eliminar este problema y a la vez auxiliar a los administradores es esencial establecer un inventario de recursos naturales con potencial económico la cual se enfoque hacia los recursos de vegetación. Se considera que la vegetación es buen índice ya que es:

a) relativamente estable;
b) relativamente fácil de trazar en un mapa empleando un mínimo de equipo especializado;
c) posible trazar un mapa de amplias extensiones de terreno;
d) útil para los administradoes de recursos naturales como un indicador específico del tipo de medio ambiente.

El Grand Canyon presenta un reto muy especial para el especialista de inventarios. La diversidad geológica y de terreno encuentra eco en un sinnúmero de tipos de vegetación, cada uno reflejando una integración de la totalidad del medio ambiente. Como consecuencia del clima árido y semiárido así tanto como por lo difícil del acceso a gran parte de esta superficie, se requieren técnicas especiales para establecer inventarios, clasificar y trazar mapas de la vegetación.

Cualesquiera que sean las técnicas empleadas en el proceso de trazar mapas, un inventario de la vegetación se inicia con un entendimiento del uso que se propone para esta y se elabora un sistema de clasificacion adecuada. Este sistema debe conformarse a los aspectos de la vegetación que se relacionan con los objectivos que motivan la preparación del mapa de vegetación. Es de suma importancia que se establezca un sistema de símbolos para la clasificación de la vegetación que sea jerárquica ya que esto permite que en los mapas sea posible aglutinar las unidades de menor escala y separar las unidades de mayor escala. En las zonas de facil acceso de variada y diversa vegetación es deseable un sistema que permita una descripción detallada tanto como específica.

En regiones áridas y semiáridas, particularmente aquellas con amplia diversidad de condiciones ambientales, pueden correlacionarse los tipos de vegetación con diversos variables del medio ambiente, permitiendo asi establecer una imagen actual del medio ambiente. Esta hipótesis implica que la vegetación es un importante índice para identificar el medio ambiente.

Ya que es fácil trazar un mapa de la vegetación, la información que pudieran suministrar los mapas sería de considerable utilidad para el administrador de recursos naturales que tiene la responsibilidad de la toma de decisiones sobre factores ambientales pero que carece de los recursos para lograr un amplio inventario de estos factores. Aún así se requiere un considerable esfuerzo para llegar a las conclusiones apropiades.

Un importante uso de los inventarios de vegetación por parte de los administradores de recursos naturales es en el campo del manejo de la fauna silvestre en zonas áridas es el caso de las burros silvestres *(Equus asinus)* y la carencia de información acerca de la vegetación para determinar el efecto de estos animales en la vegetación y la fauna asociada en las zonas aridas del sudoeste de los Estados Unidos. El U.S. National Park Service utiliza información del inventario de vegetación adquirida recientemente para determinar la estensión de habitat apropiado para los burros y establecer asimismo la condición de la vegetación y de la fauna silvestre en las áreas ocupadas por o carentes de burros silvestres.

Si hemos de hacerle frente adecuadamente a los problemas de manejo de recursos en el futuro debemos utilizar los sistemas de sensores remotos y otros implementos científicos a nuest alcance par establecer muy completos inventarios de recursos. Los inventarios de recursos de vegetación pueden proporcionar respuestas adecuadas a los problemas que enfrentan los administradores de recursos en zonas áridas.

Estado Actual del "Castor" (Castor canadensis mexicanus) en el Estado de Nuevo León, México.[1]

Jorge A. Bernal Landín[2]

La planicie costera del Golfo con -- 36,000 km^2 es la más extensa región fisio gráfica de Nuevo León. Está recorrida -- por cuencas y afluentes que constituyen - importantes biotopos, habitados por una - variedad faunística muy interesante. Las orillas de estas cuencas están cubiertas por vegetación riparia, formada por hierbas, arbustos y árboles, que en ciertas - áreas todavía constituyen refugios naturales y a la vez proporcionan el sustento a varias especies faunísticas ribereñas.

Uno de los componentes de esa interesante fauna lo constituye el castor. Desde hace casi un siglo, se conocía la presencia de este roedor en territorio mexicano, sin que se determinara su distribución al sur del Río Bravo. Según Leopold (1959), existen poblaciones locales aclimatadas a vivir en ríos que atraviesan -- las planicies semiáridas. Solamente en - estas condiciones se encuentran los castores en México.

A pesar de la zona tan restringida - que comenta Villa (1954), el castor a 24 años del primer estudio de esta especie - en el norte de la República Mexicana, en la actualidad, su radicación se ha ampliado más al sur a través de los diferentes ríos y arroyos, aunque su población no lo ha hecho.

La infraestructura, la influencia de la agricultura, el pastoreo, el uso del agua, el trampeo intermitente y los deportistas que año con año abarrotan los ríos y afluentes de la cuenca del Bravo, han - diezmado y diseminado la población del -- castor en Nuevo León.

El castor es una de las especies que se encuentra al borde de la extinción, -- fundamentalmente por los escasos conocimientos sobre la función que desempeña en la naturaleza. Esto motivó para que se - realizara el presente estudio y así poder determinar la distribución actual del castor y algunos datos ecológicos de su habitat en Nuevo León.

GENERALIDADES DEL AREA

Localización

El estado de Nuevo León se encuentra al Noreste del país. Sus límites son: al norte con los Estados Unidos, a través de la Congregación Columbia; al noreste con el Estado de Coahuila; al oeste con el Estado de Zacatecas; al sureste y sur el Estado de San Luis Potosí; al noreste, este y sur con el Estado de Tamaulipas.

Su posición geográfica está determinada por los paralelos 23° 10' 27" y 27° 46' 06" de latitud norte y los meridanos 98° 26' 24" y 101° 13' 55" de latitud --- oeste.

El Estado tiene un área de 65,103 -- km^2, la distancia de estremo norte al extremo sur es de casi 500 Km.

METODOLOGIA

Las observaciones de campo se realizaron a lo largo de los diferentes ríos y arroyos en la parte noroeste del Estado, en donde se obtuvo información de la distribución y de la densidad de su población.

Contar el número de colonias de un - río o arroyo dado y estimar el número de castores en cada colonia es una forma práctica de determinar la población.

Se emplearon dos métodos de censo para esta especie, éstos fueron:

- Navegando en ríos y arroyos, si--- guiendo el curso de éstos desde su naci-- miento hasta su desembocadura y contando las colonias activas, basándose en las -- huellas características de la actividad - de estos roedores en árboles y arbustos, así como madrigueras y echaderos.

El siguiente método fue probado en - un río:

- Caminando por toda la ribera, y haciendo las mismas observaciones que en el caso anterior.

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[1] Trabajo presentado en el Evento Internacional, "Inventarios de Recursos de Zonas Aridas", La Paz, B.C.S., Mexico, Nov. 30 - Dic. 6, 1980.

[2] Centro de Investigaciones Forestales del Noreste. I.N.I.F., Mexico.

Dicho método se probó en 10 ríos y arroyos que por sus condiciones sólo permitió este procedimiento.

Ambos métodos proveen datos confiables, pero son un poco lentos.

Para la evaluación del número de castores por cada colonia se eligieron al azar varias localidades de los diferentes cursos de agua; y a base de observaciones directas se determinó el número de castores por cada punto, además, en estos lugares se obtuvieron datos sobre su comportamiento.

Para el estudio de la vegetación, se colectaron ejemplares y se fotografió cada área, especialmente los árboles roídos.

La descripción de la localidad se basó principalmente en el poblado más próximo para conocer con exactitud cada colonia. Las medidas de las áreas de actividad se tomaron en cuenta desde donde aparecen sus huellas hasta donde no había ningún rastro. Además se incluye la vegatación característica de cada área.

RESULTADOS

Distribución del castor (Castor canadensis mexicanus) en el Estado de Nuevo León, México.

La planicie costera del Golfo es recorrida por once ríos y arroyos principales; éstos fueron estudiados en 860 Km. donde se localizaron 78 colonias de castores de las cuales 64 estaban activas. En 17 se observaron "diques" con un total de 256 ejemplares en el estado.

Los afluentes del Río Bravo en donde se localizaron indicios de castores son:

- Río Salado: 19 colonias activas con tres "diques" y una colonia abandonada.

- Río Sabinas: actividad reciente en cinco lugares con cinco "represas" y seis colonias abandonadas.

- Río Alamo: trece colonias activas con cinco "represas".

- Arroyo Macho: dos lugares activos con sus "represas".

- Río Agualenguas: dos localidades activas.

- Río San Juan: se observaron 18 lugares activos con una "represa" y cuatro colonias abandonadas.

- Río Santa Catarina: un lugar abandonado.

- Arroyo Blanquillo: una colonia abandonada.

- Río Pilón: tres localidades con actividad reciente con una "represa" y una colonia abandonada.

- Arroyo Mohinos: un lugar activo.

- Río Lobo: un lugar activo.

HABITOS ALIMENTICIOS

Estado Natural

Los castores son hervíboros. Tienen preferencia por los árboles que se encuen

TABLA No. 1 Datos de la población del castor, en el Estado de Nuevo Leon, en los diferentes ríos y arroyos de 1977 a 1978.

NOMBRE DEL RIO O ARROYO	LONGITUD EN KM.	NO. DE COLONIAS ACTIVAS LOC.	NO. DE CASTORES APROXIMADAMENTE	METODO DE CENSO
Salado*	135	19	76	Caminando
Sabinas	120	5	20	Caminando
Alamo*	60	13	52	Caminando
Del Macho	15	2	8	Caminando
Agualenguas	30	2	8	Caminando
San Juan*	180	18	72	En Lancha
Sta. Catarina	100	0	0	Caminando
Blanquillo	15	0	0	Caminando
Pilón	80	3	12	Caminando
Mohinos	70	1	4	Caminando
Lobo	55	1	4	Caminando
T O T A L	860	64	56	

*Ríos Pincipales

tran cerca de la orilla. Para roer efectúan el corte en forma horizontal en toda la circunferencia del tronco, hasta tener la apariencia de dos conos opuestos por la base. En ocasiones se observó que hacen este procedimiento, pero se caen antes de ser terminados por la influencia del peso, aire o porque están más inclinados hacia un lado.

Prefieren la corteza. Derriban los árboles para alcanzar las ramitas y hojas tiernas; hacen varios cortes para arrastrarlos al agua y fabricar sus "diques" o sus "echaderos" donde se alimentan con mayor seguridad.

El orden de preferencia de las diferentes especies de plantas son las siguientes:

Sauce	Salix nigra
Sauce	Salix bonplandiana
Sabino	Taxodium mucronatum
Huizache	Acacia farnesiana
Zacates	Varias especies
Jarilla	Baccharis glutinosa
Fresno	Fraxinus americana
Tule	Typha aurantifolia
Tule	Typha latifolia
Palo blanco	Celtis laevigata
Mezquite	Prosopis glandulosa
Jaboncillo	Sapindus saponaria
Maíz	Zea maíz

Por lo general la actividad de este roedor se realiza por la noche y en ocasiones en algunas horas del día.

Muchas personas creen que el castor se alimenta de peces, porque en las orillas se han encontrado esqueletos o deshechos. Otros pescadores o campesinos al sacar sus redes o líneas de anzuelos observan que sus peces están mutilados y piensan que éstos son comidos por el castor; sin embargo, su fundamento es falso porque el daño a los peces se debe a tortugas, principalmente.

Cautividad

El ejemplar donado al departamento de vertebrados, procedente del Río Sabinas, fue una hembra sub-adulta y hubo la oportunidad de estudiarla por un espacio de 15 días.

Se le proporcionaron diferentes legumbres que fueron aceptadas por el castor de mayor a menor grado: lechuga (Lactuga sativa); zanahoria (Dacus carota); rábano (Raphanus sativus); col repollo (Brassica capitata); camote (Ipomea batata).

HABITOS DE CONSTRUCCION

Diques o Represas

Una de las características notables en las áreas en donde habitan, son sus construcciones, en las que demuestran su capacidad para edificar dichas estructuras apareciendo como los "Ingenieros de la Naturaleza".

El propósito de construir estos "diques", es almacenar el agua para que el nivel sea profundo, ancho y constante; esto da protección de sus predatores.

Durante el estudio, observamos que usan diversos materiales para su construcción: ramas, troncos principalmente; a la vez piedras, lodo, zacates y raíces, además de otros materiales no muy comunes como botes y botellas que de una u otra forma son apilados para formar una fuerte y ancha barrera hasta que llega a una altura deseada para mantener en buen estado la represa. Todos los miembros de la colonia ayudan a conservarla, con excepción de los más pequeños.

Esta especie no siempre edifica sus construcciones, ya que sus represas sólo son necesarias en los pequeños cursos de agua o donde el nivel es bajo. En cambio, en ríos caudalosos y lagos no son necesarias estas construcciones, como sucede en el río San Juan, que les proporciona protección. Este río es el más caudaloso de la planicie costera del Golfo y cualquier construcción que haga se destruye. Esta es la razón por la cual casi no hay "represas" y la única observada fué en un recodo de este río, al la altura del Ejido Pueblo Nuevo, Jurisdicción de Cadereyta Jiménez, Nuevo León.

Madrigueras y Echaderos

Las madrigueras más comunes que construyen los castores en Nuevo León son excavaciones en las margenes de los ríos y arroyos. Tienen varias entradas, en las superficies de las aguas y abajo de las mismas; estos túneles tienen diferentes funciones. Se conectan con tierra firme, en donde construyen respiraderos; éstos se localizaron a diez metros de la orilla. Además, les protege; son dormitorios; almacén de alimentos y constituyen las maternidades.

De las aberturas hechas en la superficie, se tomaron medidas de las entradas a los túneles, 32 cm. de altura por 4 cm. de ancho en promedio. Por lo general tienen varias entradas por arriba y por abajo de la superficie del agua, cuya distan

cia varía de 70 cm. a 15 cm. Las galerías miden aproximadamente de uno a dos metros transversalmente y de alto unos 60 cm. Su piso tiene esquirlas de madera, corteza, hojas y zacates.

Los echaderos son simples pozos que se encuentran en las márgenes de los ríos y arroyos.

IMPORTANCIA ECOLOGICA Y ECONOMICA

La importancia que representa el castor, al igual que muchas especies en nuestro estado, no han sido valoradas, haciéndose notorio especialmente al sistema educativo.

Estos "ingenieros de la naturaleza" forman "diques" cuyo beneficio directo es al hombre, ya que la función de retener el agua evita su rápido y total escurrimiento, evitando la erosión y gracias a ésto, en sus márgenes se desarrollan árboles y arbustos; forman abrevaderos y habitats para otras especies silvestres, se conservan los peces que deben ser aprovechados con método por el hombre. Es, en fín, un verdadero trabajador de la naturaleza. En su descanso remueve el fango, dando lugar a la dispersión de semillas importantes dentro de un ecosistema acuático.

Las acciones que alteran o equilibran el medio, pueden ser benéficas o dañinas para el hombre. Estas causas se observaron en este estudio, las cuales se describen a continuación.

En la jurisdicción del Ejido Pueblo Nuevo (cadereyta, Jiménez), en el río San Juan, año de 1975, en época de lluvia, el río creció; al bajar el nivel la corriente cruzaba la propiedad privada. En estos lugares los castores construyeron sus "represas". El ganado obtuvo un abastecimiento de agua.

En otras áreas, los campesinos o los agricultores efectúan riegos a sus sembradíos de los estanques construídos por el castor. De esta manera se ahorran el gasto de construir su "represa".

Con sus barreras almacenan el agua, protegiendo a todo aquel organismo que dependa de ella.

Además, ayuda a controlar el nivel de las aguas y de éstas resulta una suceción ecológica, creando habitats, en donde una diversidad de plantas y animales se relacionan.

En los diferentes ríos y arroyos del estado de Nuevo León, donde se realizó el estudio, se encontraron muchos animales que son beneficiados con la construcción de sus "diques". En cuanto a peces se refiere, 10 especies son las que se benefician, 2 de anfibios, 8 de reptiles, 16 especies de aves y 11 especies de mamíferos. Además de estas especies hay muchas más que acuden a los estanques.

De acuerdo con las observaciones de campo, concluímos que el abandono de las áreas del castor fueron porque en el área escaseó el alimento y efectuaron un movimiento río abajo o arriba; además, los disturbios provocaron la huída en la misma forma.

En algunos lugares en donde habitan castores, las actividades de éstos pueden ser "perjudiciales" al hombre, los comentarios o las causas que se informaron a través de este estudio son:

En las milpas de maíz, cuando se encuentran cerca de la ribera, como sucede en el río San Juan a la altura de Arcabuz (Taumalipas), y en Potreros (Cadereyta Jiménez). En esta región era trampeado porque hacía daño a los cultivos. No se valoró el daño, pero se consideró que era mínima la acción de esta especie sobre los cultivos.

Otros comentarios fueron que los árboles eran destruídos por esta especie, como sucedió en la congregación 5 de Mayo. Los campesinos utilizaron alambre de púas, enrrollándolo en la base hasta un metro y medio para protegerlos; no se informó si por esas causas se mataban a los castores.

CONCLUSIONES

El castor habita en tres áreas diferentes: la primera en ríos caudalosos, anchos y profundos. Esta es la más importante para la superviviencia de la especie, de acuerdo a las observaciones de campo que se realizaron en los 11 ríos y arroyos principales. La segunda es aquella en la que el castor sale de los principales afluentes y construye represas en arroyitos cuyo caudal tiene fluctuaciones durante el año y lo obliga a edificar sus represas. La tercera son las pequeñas presas donde no se levantan sus construcciones.

De acuerdo a la metodología empleada, las dos clases de censo utilizadas se consideran las más apropiadas para esta especie.

La presencia del castor en la planicie costera del Golfo, trae un mayor beneficio a las comunidades, tanto ejidales como privadas por sus acciones de conser-

var agua. Si consideramos que en los últimos años se ha sentido más la escasez - de lluvia en toda esta zona fisiográfica. La influencia de esta especie ha sido importante para la conservación de muchas - otras especies cuyo beneficio indirecto o directo es al hombre. Esto a pesar que - se observó en tres lugares, como el castor hacia "daño" a las milpas.

El castor no es perseguido ni cazado para fines comerciales como en otros lugares del vecino país, en donde se le caza para la obtención de su piel y otros derivados. Quizá en Nuevo León, la influencia de los pescadores que accidentalmente los capturan, son una de las causas fundamentales que la población no sea mayor de -- 256 ejemplares.

Aunado a los escasos conocimientos - de sus mecanismos biológicos son causas - del porqué han diezmado a esta especie. - Además, otros consideran que la dieta alimenticia del castor son los peces y los - cazan porque creen que acaba con ellos.

Se requiere que las leyes vigentes - sobre protección de la fauna silvestre, - sean aplicadas con todo el rigor, para todas aquellas personas que por el deseo -- de matar lo hacen. A estas personas debera aplicárseles el castigo que les corresponda.

Concluimos que de acuerdo a la población que se estimó en este estudio, el -- castor desaparecerá de los arroyos intermitentes para esta década y del Río San Juan para fines de este siglo.

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SUMMARY

The beaver lives in three different areas. According to a field study made on 11 rivers and deep brooks, deep rivers are the most important for the survival of this species. The small brook where the volume of water fluctuates during the year is the next area of importance for their habitat. In these areas the beavers are forced to build dams in order to survive. The third area is where there is already a dam.

The two types of census employed for the population study of this rodent are considered the best according to the method utilized. In the Gulf coastal plains, the presence of the beaver is very beneficial to private and to common public land due to the water storage activities of this species, and to the fact that these physiographic zones have suffered a severe drought during the last few years. The presence of the beaver is of importance also for the conservation of many other species which directly or indirectly benefit man, notwithstanding the fact that the beaver will destroy some cornfields in these areas.

The beaver is not hunted down for commercial purposes as it is in other places of the neighboring country, where it is sought after for its fur and other derivatives. Perhaps in Nuevo León the influence of the fishermen who accidentaly capture them is the reason why the beaver population is not greater than 256. Others believe that since the beaver feeds mostly on fish, fishermen consider it a threat to their business, and kill it.

At present this species is being threatened due to the lack of knowledge concerning its biological mechanism, and due to the fact that they are hunted by fishermen.

The existing laws for the protection of wild animals must be enforced, and the beaver hunters should be prosecuted.

According to the beaver population that is estimated in this study, our conclusion is that the beaver will disappear from the streams during this decade, and from the San Juan River by the end of this century.

La Cartografía, Expresión Sinóptica del Inventario de Recursos[1]

Fausto García Castañeda[2]

Abstract. - It is presented the arid and semi-arid lands mapping coverage, as a synoptic expression of the resource inventories. On a chart is noted coverage in percent for every thematic map and scale produced by DIGGETENAL.

El inventario de recursos de una región o de un país, se efectúa a diferentes niveles de profundidad, para satisfacer objetivos específicos de la investigación, y sus resultados se expresan en diferentes formas, tales como informes, cuadros, gráficas y mapas.

La Dirección General de Geografía del Territorio Nacional, (DIGGETENAL), dependiente de la Coordinación General de los Servicios Nacionales de Estadística, Geografía e Informática, realiza desde 1968 el inventario de recursos del país y publica sus resultados en mapas temáticos a diversas escalas que muestran, por medio de símbolos convencionales, una visión sinóptica de la distribución espacial y de las principales características de los recursos.

Esta cartografía está concebida para proporcionar información a los numerosos grupos de estudiosos de la problemática del territorio nacional, es decir, está dirigida para satisfacer una demanda de carácter universal, por lo cual para ciertos grupos el nivel de información que presentan excede sus demandas, para otros la información es congruente con la demanda y finalmente para un tercer grupo, la información, aunque insuficiente para sus fines, constituye un marco de referencia y una plataforma para realizar investigaciones más detalladas.

Los mapas DIGGETENAL son el resultado de una investigación multidisciplinaria basada fundamentalmente en las técnicas de fotogrametría, fotointerpretación y percepción remota.

Los temas que cubre el sistema cartográfico de la Dirección General de Geografía del Territorio Nacional son:

Climatología. - Se publicó una primera carta climática a escala 1:500 000. Actualmente se trabaja en las Cartas de Temperaturas Medias Anuales, de Precipitación Total Anual y de Climas, a escala 1:1 000 000.

Topografía. - Se ha publicado la Carta a escala 1:1 000 000 (4 hojas) y se trabaja en las Cartas a escalas 1:250 000 y 1:50 000.

Uso del Suelo, Geología y Edafología. - Se trabaja en las escalas 1:1 000 000, 1:250 000 y 1:50 000.

Uso Potencial. - La Carta de Uso Potencial agropecuario y forestal se trabaja a la escala 1:50 000.

Hidrología. - Las Cartas de Aguas Superficiales y de Aguas Subterráneas se elaboran a escala 1:250 000.

[1]Documento presentado en la reunión sobre Inventarios de Recursos de las Tierras Áridas (La Paz, México, noviembre 30 - diciembre 6 de 1980).

[2]Fausto García Castañeda es asesor técnico de la Dirección General de Geografía del Territorio Nacional, Sría. de Programación y Presupuesto, México, D. F.

Turismo.- La Carta Turística se ha publicado a escala 1:1 000 000.

La Dirección General de Geografía del Territorio Nacional, agradece el interés de los organizadores de la Reunión sobre Inventarios de Recursos de las Tierras Aridas, en conocer la cartografía que produce.

Con respecto a las zonas áridas y semiáridas de México puede decirse que comprenden una porción muy importante del país que representa el 55% de su superficie.

CLIMA[3]		AREA[4] (Km2)	%
Muy árido	(BW)	500 000	25 %
Arido	(BSo)	280 000	14 %
Semiárido	(BSi)	320 000	16 %
		1 100 000	55 %

Como en las zonas áridas y semiáridas se presentan serios problemas de planificación del desarrollo socioeconómico, se consideraron prioritarias dentro del programa del leventamiento cartográfico del país.

El cubrimiento de las zonas áridas y semiáridas del país, con los diversos productos cartográficos DIGGETENAL se indica en el siguiente cuadro.

CUBRIMIENTO CARTOGRAFICO DE LAS ZONAS ARIDAS Y SEMIARIDAS (%) (OCTUBRE DE 1980)

CARTA / ESCALA	1:1 000 000	1:500 000	1:250 000	1:50 000
Climática	17	100	-	-
Topográfica	100	-	51	70
Uso del Suelo	17	-	-	43
Geológica	17	-	-	33
Edafológica	17	-	-	32
Uso Potencial	-	-	-	27
Hidrológica (Aguas Sup.)	-	-	6	-
Hidrológica (Aguas Sub.)	-	-	6	-
Turística	100	-	-	-

[3]Sistema de Koeppen, modificado por E. García.

[4]Según Carta de Climas de la República Mexicana, escala 1:500 000 (CETENAL-INST. DE GEOG. DE LA U.N.A.M.).

PANEL D

Desert Land Use Planning Based upon Field Sampling and Remote Measures[1]

Stahrl W. Edmunds[2]

Abstract.--Field sampling and remote sensing are economic means to develop land use plans which provide for special or multiple use of desert regions, provided the data gathering is pre-planned to fit the land use goals. Two examples are given of the use of remote measures, one for geothermal energy development in Imperial County, the other for wilderness protection in the California Desert Plan.

Inventorying of desert lands is costly due to their vast size, remoteness, and variation. For economy, the inventory should be coupled with a decision process to reduce data requirements to those facts which will influence decision outcomes. Frequently decision outcomes are reflected in land use plans. Therefore, specifying the land use decision requirements first will help specify and simplify inventory data needs. Such a process was used in developing a land use plan for geothermal energy development in Imperial County, and to a limited extent in analyzing data needs for the California Desert Plan.

FIELD SAMPLING AND REMOTE MEASURES

Sampling the desert biom is approached by field inventories which make transects and counts of vegetation and zoological species in a small sample of the total land area based upon random and grid location sites, plus special anamolous sites suspected of being rare-species habitat. These sample inventories establish a pattern of plant communities which become the basis for projection to the desert universe by remote sensing.

Remote sensing maps are prepared from low altitude color and infra-red photography, by flying a grid-line flight pattern. The low altitude remote sensing maps are tied into the sample field inventory (by the grid and sample sites) by establishing pattern recognition of plant communities. The low altitude pattern of plant communities are extrapolated further to the desert universe by high altitude remote sensing maps which cover the entire desert region under study. Anamolous or rarer-species communities are sampled at higher rates and projected to the total desert region via low and high altitude pattern recognition.

Geologic and mineral featers of the desert are identified by sample field inventory measures of gravity anamolies, temperature profiles, ground and aeromagnetic methods, seismic samples, and electrical resistivity measures. These are then related to remove sensing photographic maps which identify fault structure and surface features which indicate geologic activity.

The sum of the field samples and remote measures provide the ability to categorize broad areas of the desert into single and multiple purpose land uses, such as agricultural land (by type), flood plain, range land (by type), forest (by type), desert plant communities (by type), scenic, recreational, mountainous, rare habitat, and potential mineral resource areas. These land use patterns then may form the basis of public land management programs in which government or private parties are authorized to engage in further investigation, inventorying, or uses. The value of such land use plans is that they will tend to maintain public and desert lands for their highest and best uses, whereas unmanaged desert lands tend to be damaged by and deteriorate to low-utility human occupation - thus extending desertification.

Two examples of the use of field sampling and remote sensing will be given, one for geothermal energy development in Imperial County, the other for wilderness protection in the California desert.

GEOTHERMAL ENERGY DEVELOPMENT IN IMPERIAL COUNTY

Imperial County, California, lies in the Salton rift where two tectonic plates join in a strike-slip fault at the junction of the San Andreas, Brawley and Imperial fault lines. This trapizoidal shaped block rotates counter-clockwise as the continental plates move, causing the valley to spread

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[1] Paper presented at the international workshop, Arid Land Resource Inventories: Developing Cost-Efficient Methods, Nov. 30 - Dec. 6, 1980, La Paz, Mexico.

[2] Director, Dry Lands Research Institute, University of California, Riverside.

at the rate of about 2 centimeters per year and opening fractures in the sedimentary overburden down to depths of 5 to 6 kilometers to the basement rock. The intrusion of hot magma at these depths heats the rock by conduction, and the rock in turn heats the surrounding aquifers, where water is trapped between impermeable layers of strata, by convection. Imperial County has six known geothermal areas (KGRA's); and the entire field appears to be an extension of the geological regime of Cerro Prieto in the Mexican Sonoran desert north of the Sea of Cortez.

The problem, as seen by the land use planners in Imperial County, was how to permit the development of this geothermal resource, consistent with the existing rich agricultural economy, and consistent with the wilderness and recreational uses of the desert surrounding the area of irrigated agriculture. The economic value of the geothermal resource is considerable, since it is believed to be ultimately capable of producing 10,000 megawatts of electric power, if heat is extracted from fluid alone, and perhaps 20,000 megawatts of electric power if heat can also be extracted from the rock. These figures compare with about 40,000 megawatts of electric power currently used in California.

Still, the agricultural economy already produces a half billion dollars worth of income in crops, and much of the employment in the area is agriculturally based. Moreover, there are a number of recreation uses of the desert in the region, particularly in the sand dunes area east of El Centro.

The land use planners then set several goals for the potential development of geothermal energy, which included the following issues and policies:

1. Optimum use of the resource.
2. Prevent subsidence.
3. Monitor seismic activity
4. Preserve agricultural uses of land.
5. Conserve water use.
6. Foster non-electric uses of geothermal energy.
7. Measure economic, social, and fiscal impacts.
8. Determine and mitigate environmental impacts.
9. Design county regulations to protect agriculture and environment.
10. Administer land use zoning flexibly to encourage development.
11. Minimize transmission corridors.
12. Inform public of the land use planning.

These goals dictate data-gathering requirements including land use identification and mapping which cover: crop identification by ownership parcel, geothermal anamoly locations, land grading, water usage, seismic monitoring, existing corridors, existing zoning, and environmental impacts. The method for creating this land-use data base was as follows:

1. A parcel map of existing ownership was obtained from the assessor's office.

2. Water usage and drainage by parcel was obtained from the irrigation district.

3. Zoning and corridor maps were obtained from the public works department.

4. Field sampling was used to identify typical crops to parcels, as well as drainage pattern and slope.

5. Remote sensing was accomplished by an overflight at 2,000 feet with color and infra-red photography.

6. The aerial photographs were analyzed as to color and pattern to identify crops, field tilling, and slope; and these patterns were matched to the ownership parcel map.

7. The crop patterns were analyzed in relation to prospective geothermal energy sites to determine proximity and crop value compared to environmental hazard.

8. Ranges of estimates were made as to effect of subsidence or seismic activity of field tilling and irrigation.

9. Potential air pollution emissions and water effluents were examined in relation to wind and hydraulic flow to determine potential crop-value damage based upon proximity and existing cropping.

10. Seismic measures were established to determine background seismic activity, and a seismic monitoring network was proposed for installation along with geothermal wells.

11. Overlays of typical zoning for geothermal wells were superimposed on the agricultural parcel maps, which included transmission corridors.

12. A floating zoning was developed to facilitate location of wells where discoveries might be made, with minimum disturbance of agriculture or existing infrastructure and corridors.

The outcome of this analytical process was the ability to accommodate geothermal development with little impact upon agriculture. Engineering design analysis indicated that with slant drilling the geothermal platforms would require only one percent of the 500,000 agriculture acres in use. Transmission pipes to collect the geothermal fluid could parallel existing corridors, as could electric lines to wheel the energy out. Reinjection of the geothermal fluid would prevent land subsidence, and thus mitigate any effects upon tilled fields, as well as preventing contamination of surface waters. Power plant cooling could be provided by agricultural

drain water, with economic treatment, and thus conserve fresh water for agriculture or domestic use. Few high value crops, like asparagus or lettuce, were close enough to the proposed sites to present a hazard of air pollution damage; and those that were could be relocated by reallocating the water rights. The outcome, on the whole, then was favorable to geothermal development and Imperial County has since been issuing permits and zoning under the land use plan.

An example of an aerial photograph for the Salton Sea KGRA (known geothermal resource area) is shown in Exhibit I. The photograph shows the pattern of crops in the area, which can be distinguished by their color and density. Within a single parcel, the slope is partially revealed by gradations of the color value. Enlargements of the infra-red photographs for a parcel show lines of underground filed tilling. One of the geothermal test sites can be located as a tiny dot on the map in the lower center of the land mass, about one inch up from the bottom.

EXHIBIT I

The second aerial photograph, Exhibit II, shows the East Mesa KGRA which is almost entirely located on open, non-agricultural land. Some of the hills, rills, and brush are apparent in the right, two-thirds of the photo. The agricultural land, on the left one-third, is marked off by the High-Line irrigation canal which brings irrigation water to the east valley. Just to the right of the High-Line canal, about one-fourth of the way up from the bottom, above the diagonal road, can be seen an irregular black pond with a small dark square to the northeast. This is a Bureau of Reclamation test facility for trying to develop desalinized water through the use of geothermal steam.

The last illustration of Imperial Valley, Exhibit III, is a crop distribution map by ownership parcel for the Herber KGRA. This map represents a transfer of the identification from an aerial photo to a parcel map, after identifying crop usage. The darker shaded areas are generally high-value asparagus, lettuce, and vegetable crops which might be affected by air pollution if a geothermal well were in close proximity. The lighter, cross-hatched areas are field and tree crops which are unlikely to be affected. The geothermal test wells are generally in the lower left of the map, in the cross-hatched area.

CALIFORNIA DESERT PLAN

Next let us shift our attention to another example of the use of field sampling and remote sensing for land use planning, this time to a more open area in which the planning is concerned with wilderness preservation. The Bureau of Land Management is charged with administering a public domain of about eleven million acres of land in southeastern California. The region is bounded by the Sierra Nevada on the west, Mono Lake and Death Valley on the north, Colorado River on the east, and Mexico on the south. This region is generally the extension of the Sonoran Desert of Mexico and is usually referred to as the Colorado and Mojave deserts in California. Much of the land in the southern and southwestern portion is privately held as agricultural or subdivision land, for example in Imperial Valley, Coachella Valley, Palm Springs, Riverside, and San Bernardino. However, to the north and east, the land is largely owned by the federal or state governments, or by a checker-board pattern of private ownership.

This area is much used, and sometimes abused, for transportation and utility corridors, military reservations, grazing, mining, recreating, and off-road vehicle usage. The vegetation varies from: pine forests in the northwestern mountains; to Joshua tree, brittlebush and sage in the high deserts; to creosote bush and dune grass in the low deserts. The desert pavement is generally thin and easily broken by vehicles. Once broken the desert suffers from wind and water erosion which leaves irreversible scars on the surface. The animal life of the desert is diverse and profuse, though not easily visible, as it is commonly made up of insects,

EXHIBIT II

rodents, reptiles, hares, and tortoise. The disturbance of the desert easily upsets the balance of these species and of the ground cover upon which they depend. Vehicle traffic quickly crushes, for example, the creosote bush which may have taken from a century to three thousand years to develop.

Given this fragility, the protection of the desert from overuse has been one of the concerns of the Bureau of Land Management.

Their first endeavor, then, was to inventory the desert resources as they exist, the land structure, uses, plant and animal species. The survey methods included the following:

1. Aerial photography was undertaken for overflights at six to eight thousand feet along grid-structure flight paths. The photo analysis was used to establish broad plant communities and land structures.

2. Field survey teams inventoried extensive plant and communities by observation, species identification, species counts through both mobile and foot traverse.

3. Specialized areas suspected of rare species or unusual microclimates were studied minutely by transects, species counts, growth patterns, and biomass production.

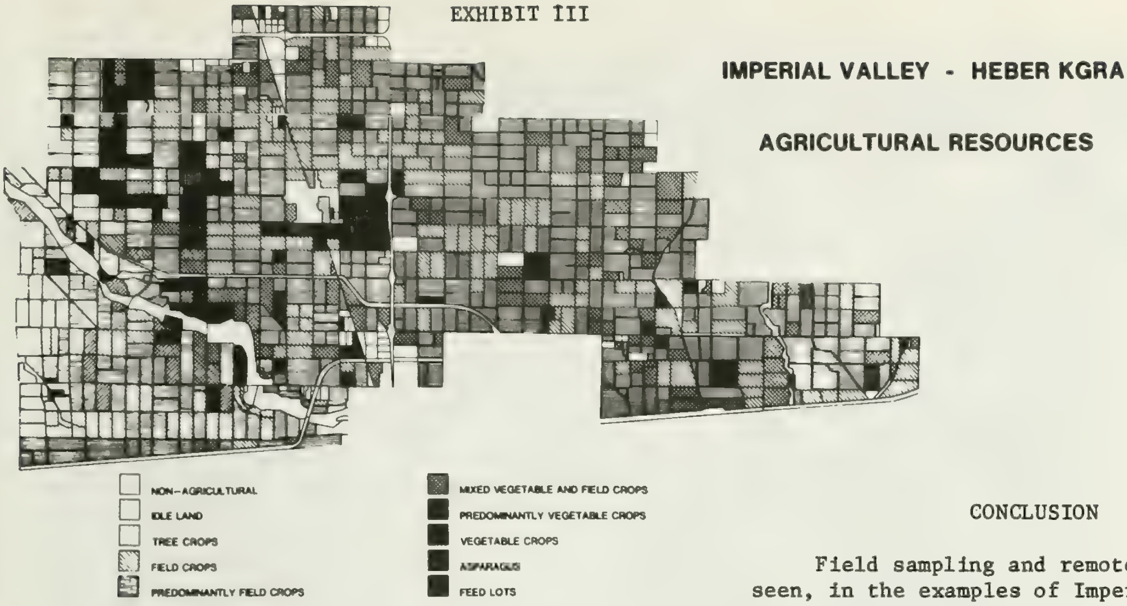
The results of these aerial and field surveys were transposed to maps identifying areas of similar plant communities. The Generalized Vegetation Map from the BLM California Desert Plan is reproduced as Exhibit IV at the end of this paper. Generally the darker areas on the map represent mountain and woodland cover. The medium shades are high diversity shrubs of the high desert. The lighter shades are the lowland scrub and grasses of the lower deserts. The legend on the exhibit classifies the main plant communities. The text of the plan itself lists the flora and fauna in detail.

Given this inventory of the land resources of the California desert, the Bureau of Land Management next developed several land use planning elements to deal with the multiple uses of the desert. These plan elements are:

1. Cultural resources.
2. Native American values.
3. Recreation
4. Wilderness
5. Motorized vehicle access.
6. Energy/utility corridors.
7. Mineral development.
8. Livestock grazing.
9. Wildlife.
10. Land tenure adjustment.

For each of these several purposes or uses, BLM then developed a set of alternatives on how the land might be managed. These alternatives are:

EXHIBIT III



1. No action alternative, or do nothing.

2. Protection alternative, which would optimize the protection of the natural environment, especially flora fauna.

3. Use alternative, which would optimize the human uses of the desert, particularly recreation, economic uses, and off-road vehicle access.

4. Balance alternative, which would try to protect the rarest of the species, but allow substantial human uses in low desert areas.

The protection alternative for the wilderness and wildlife element close to human and vehicle access much of the mountain and high desert regions with diverse and complex biological communities, as seen in the medium to dark shades of Exhibit IV.

Conversely, the use alternative of the motor vehicle access element would open much of the low desert to vehicle traffic, despite its destruction of the desert pavement and the creosote bush communities. That is, vehicles would have off-road access to the lighter shaded areas of the low deserts in Exhibit IV.

The final determination of which use or protection alternative to permit for each plan element is still in the hearing and final determination stage. Substantial pressure groups exist, especially from recreation vehicle owners, to open all of the desert to all uses. The BLM is trying at least to preserve the rare species and unusually scenic areas for limited human use, but the environmental supports are neither as numerous or vociferous as the vehicle recreationalists. The result, at best, might be the balanced use alternatives.

CONCLUSION

Field sampling and remote sensing can be seen, in the examples of Imperial County and the California Desert Plans, to be useful methods for identifying land uses and their alternatives. The methodology is applicable to a wide range of other open-space and land use planning problems, such as natural resource identification, energy/utility corridors, plant siting, recreational areas, strip-mine reclamation, new town, or rural subdivision planning. The methodology is straightforward and practical. The steps are to identify the planning goals and data needs, inventory the open space on a sample basis first by field survey, then to make an extensive survey by aerial photography, which can subsequently be transposed to land use and zoning maps. While the interpretation of aerial photography involves considerable manhours and cost, it is less expensive and more efficient than alternative methodologies.

RESUMEN

El muestreo de campo y las mediciones remotas han demostrado ser métodos útiles en la identificación de alternativas para el uso de la tierra en Imperial County y los desiertos californianos. Dichos métodos se pueden también aplicar a otros problemas en el área (genérica) de planificación del uso de tierra y espacios abiertos, tales como identificación de recursos naturales, localización de empresas, áreas de recreo, minas, nuevas ciudades o planificación de subdivisiones rurales. Los métodos son simples y prácticos, y las etapas que comprenden son: identificación de objetivos; identificación de los datos a emplear; inventario del terreno a base de planimetría, primero en una muestra reducida de zonas, seguido de un estudio más completo de fotografía aérea que finalmente se transforma en mapas de zonas. Aunque la fotografía aérea exige una cantidad considerable de horas de trabajo y es aparentemente costosa, finalmente resulta más eficaz y más barata que otras metodologías.

EXHIBIT IV


CALIFORNIA DESERT CONSERVATION AREA
Generalized Vegetation
— legend —
FLORISTIC ZONES
FORESTS
WOODLAND HIGH COVER
WOODLAND LOW COVER
AGRICULTURAL CROPS
1
2
3
4
5
6
7
BISHOP
INDEPENDENCE
LOS ANGELES
SAN BERNARDINO
RIVERSIDE
United States
Department of the Interior
Bureau of Land Management
DESERT PLANNING STAFF

Point Sampling for Shrub Biomass[1]

Richard O. Meeuwig[2]

Abstract.--Two point sampling methods (point transect and variable plot) for estimating shrub production or biomass are described. Both methods were found to be faster and more accurate than conventional plot sampling in field tests in sagebrush communities.

INTRODUCTION

Point sampling has been used to estimate timber volumes for nearly 30 years, based on the point concept developed by Bitterlich (1948). Point sampling has been used on range vegetation for almost 50 years, but it has generally been limited to estimation of cover characteristics and species composition. I believe that point sampling can expedite shrub biomass inventories just as it has forest surveys.

Point sampling for cover percentage is simple in theory and application. A series of points is established using a point frame, as suggested by Levy and Madden (1933), or by taking points at fixed intervals along a tightly stretched tape. Plant cover percentage is calculated by dividing the number of points striking vegetation (ns) by the total number of points (np) and multiplying by 100.

$$\text{Plant cover } \% = \frac{ns}{np} \cdot 100$$

This procedure can be used to sample shrub biomass as well as cover by including biomass per unit crown area of each tallied shrub in the calculations. Shrub biomass per unit land area can be estimated from a series of sample points by:

$$B = \frac{1}{np} \sum^{ns} (M/CA)$$

where B is estimated shrub biomass in grams per square meter of land area, np is the total number of sample points, ns is the number of sample points striking within the crown of shrubs, and M/CA is the biomass of each tallied shrub in grams per square meter of crown area.

Both crown perimeter and crown area must be clearly defined. Daubenmire's (1959) concept of canopy coverage provides unambiguous definitions of crown perimeter and area. Crown area is defined by "a polygon drawn about the extremities of the undisturbed canopy of each plant" (figure 1). Gaps within this polygon are considered part of the crown. A plant would be tallied if a point falls within its polygon even though the point might not directly strike the plant.

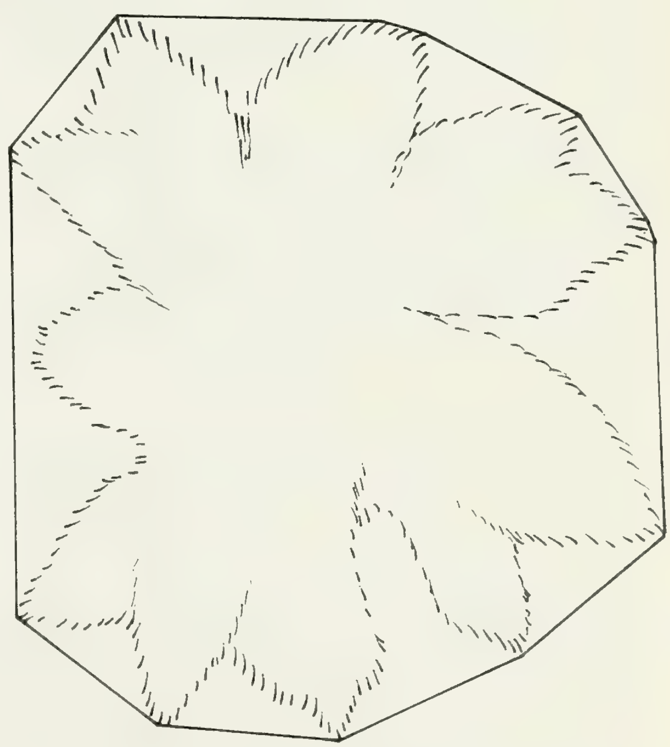


Figure 1.--The polygon around a shrub crown as viewed from above. The entire area within the polygon is considered crown.

[1]Paper presented at Workshop on Arid Land Resource Inventories: Developing Cost-Efficient Methods. La Paz, Mexico, November 30-December 6, 1980.

[2]Richard O. Meeuwig is Research Forester, USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah; stationed at Renewable Resources Center, University of Nevada Reno, Reno, Nevada.

The area of the crown polygon (CA) can be closely approximated by the equation for an ellipse:

$$CA = \frac{\pi}{4} \cdot Cx \cdot Cy$$

in which Cx is the diameter of the major axis of the crown and Cy is the diameter perpendicular to the major axis.

Shrub biomass per unit crown area (M/CA) can be measured directly on all tallied shrubs or on a subsample of tallied shrubs, or it can be estimated from appropriate regression equations based on measured crown parameters.

FIELD TESTS

Two variations of point sampling (point transect and variable plot) were field tested along with fixed plot sampling on 10 macroplots in and near the Sweetwater Research Natural Area in western Nevada. Three macroplots were in black sagebrush (*Artemisia nova*) communities and the other seven were in Wyoming big sagebrush (*A. tridentata wyomingensis*) communities. The current production of every sagebrush plant on each 10-m by 10-m macroplot was estimated by measuring its crown dimensions and using regression equations developed from clipping data of objectively selected subsamples on the macroplots. The sum of these values was divided by the macroplot area (100 m^2) to obtain the macroplot's current sagebrush production in grams per square meter. The herbaceous component was ignored in these field tests because production of herbaceous plants is not amenable to sampling by the point methods being tested.

Point Transect.--Five transects (10 m in length) were laid out 2 m apart on the macroplots as shown in figure 2. Sampling points were established at 1-m intervals along each transect, starting at the 1/2-m mark. Each shrub whose crown polygon included a sampling point was tallied. Estimated current sagebrush production ($Prod$), in grams per square meter of land area, was calculated by:

$$Prod = \Sigma(P/CA)/50$$

where P/CA is the regression estimate of current production in grams per square meter of crown area of each tallied shrub. The sum was divided by 50 because there were 50 sampling points.

Variable Plot.--This is an adaptation of Bitterlich's (1948) plotless method commonly used for estimating basal area and volume of timber stands. Cooper (1957), Kinsinger *et al.* (1960), and Fisser (1961) have used Bitterlich's method successfully for estimating shrub cover. Hyder and Sneva (1960) tested Bitterlich's method to estimate basal area of bunchgrass and found that it tended to overestimate in this application. In our tests, shrubs were tallied if their crown

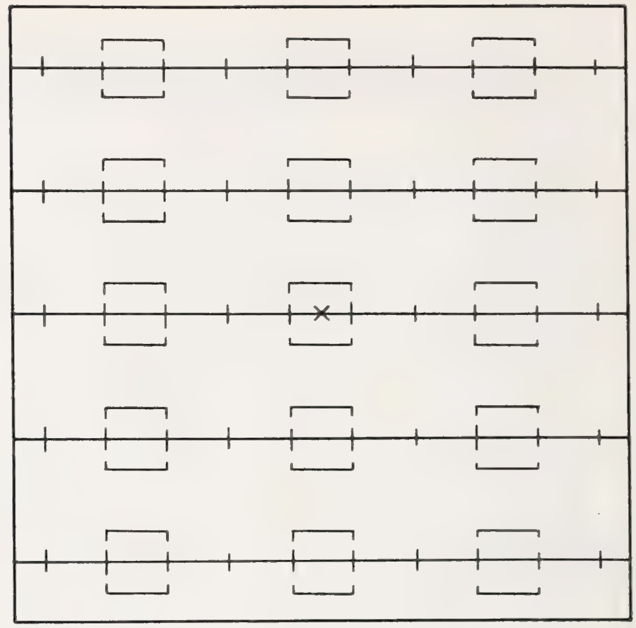


Figure 2.--Map of the 10-m by 10-m macroplot showing the locations of the five transects and the square meter plots.

polygons intercepted an angle greater than that of a 1:5 (BAF = 100 m^2/ha) angle gage when viewed from the center point of the macroplot. The angle gage used was the slope-compensating stick-type described by Meeuwig (1977). Current production, as estimated by this method, was calculated by:

$$Prod = \Sigma(P/CA)/100$$

where P/CA is the regression estimate of current production in grams per square meter of crown area of each tallied shrub. The sum was divided by 100 because the probability of a particular shrub being tallied at a single point is 100 times greater with a 1:5 angle gage than it is in simple point sampling (Cooper 1957).

Fixed Size Plots.--In addition to the two point sampling methods, shrub production was sampled on 15 one-meter square plots for purposes of comparison. All shrubs with any portion of crown in the plots were tallied along with an estimate of the proportion of their current production actually in the plot. Estimated current production on the plots was calculated by:

$$Prod = \Sigma(\hat{P} \cdot Q)/15$$

in which $\hat{P}$ is a regression estimate of current production of each tallied shrub in grams, and Q is the estimated proportion of current production actually in the plot. The sum was divided by 15 because the total area of the 15 plots was 15 m^2.

PRODUCTION EQUATIONS

Current production (foliage and succulent twigs) was clipped from 40 Wyoming big sagebrush plants and 29 black sagebrush plants in late June and early July, shortly before these species begin to shed their ephemeral leaves. The clipped material was air-dried and weighed. There were no other species of sagebrush on the macroplots except for four basin big sagebrush (*A. tridentata tridentata*) plants on one of the macroplots.

The following regression equations were developed from a series of regression analyses of the data:

Wyoming big sagebrush

$$\hat{Y} = 32 + (10.7 \cdot H + 4.2 \cdot T - 753 \cdot F) \cdot F$$

Black sagebrush

$$\hat{Y} = -67 - 0.27 \cdot T + 19.5 \cdot \sqrt{T}$$

in which Y is measured current production in grams per square meter of crown area, H is shrub height in cm, T is the number of twigs (0.5 cm in diameter) per square meter of crown area, and F is the proportion of the crown polygon actually occupied by foliage. The twig density (T) was determined by counting the total number of 0.5-cm twigs on each shrub and dividing by the shrub's crown area. Foliage proportion within the crown polygon (F) was estimated ocularly after practicing with a point frame.

The Wyoming big sagebrush equation has an R^2 of 0.75 and a standard error of estimate of 55 g/m^2 or 26% of the mean value of Y. The black sagebrush equation has an R^2 of 0.48 and a standard error estimate of 55 g/m^2 or 39% of the mean value of Y. These R^2's are smaller than those usually obtained in biomass equations, but this is caused by the use of mass per unit crown area as the dependent variable rather than the more common logarithmic equation. Dividing the mass by the crown area removes a major portion of the variance. The relatively small standard errors of estimate indicate a good fit of the data.

These equations were used to calculate the production per unit crown area of all sagebrush plants on the 10 macroplots. The Wyoming big sagebrush equation was used for the four basin big sagebrush plants. These estimates were multiplied by crown area to obtain production of each shrub for the total tally determinations and for the meter-square plots.

RESULTS

Current sagebrush production on each of the 10 macroplots, based on all sagebrush plants on the macroplots, is listed in table 1 along with the estimates by each of the three sampling methods. The first three macroplots were in black sagebrush communities and the remainder in Wyoming big sagebrush communities.

Table 1.--Sagebrush production on the 10 macroplots as determined by complete tally and as estimated by the three sampling methods.

Macroplot	Complete tally	Point transect	Variable plot	Small plots
	(g/m^2)			
1	37	34	37	27
2	48	45	51	47
3	37	33	33	36
4	57	55	47	54
5	42	34	34	62
6	61	57	53	82
7	85	74	74	71
8	72	65	81	104
9	69	74	56	71
10	50	55	50	60
Mean	56	53	52	61
Error[1]	--	6	8	16

[1]Error = $(\Sigma D^2/9)^{\frac{1}{2}}$, where D is the difference between the complete tally and the sample estimate on each macroplot.

Average sagebrush production was 56 g/m^2, according to the tally of all sagebrush plants on the 10 macroplots. The point transect estimates averaged 3 g/m^2 less and the variable plot estimates averaged 4 g/m^2 less than the total tally. The meter-square plots averaged 5 g/m^2 greater. These differences are too small to indicate bias in any of the sampling methods.

Root-mean-square error was calculated for the three sampling methods, assuming the total tally determination to be true production. The error of the plot method was 100% greater than the variable plot method and 167% greater than the point transect method. The error of the variable plot method was greater than that of the point transect method, probably because the variable plot method, as tested here, tends to sample more intensively at the macroplot center while the point transect method samples more uniformly over the plot. Error is introduced in the variable plot method if the distribution of the smaller shrubs near the macroplot center differs from the rest of the macroplot.

The three sampling methods, as well as the total tally, were applied simultaneously on each macroplot, and the time required for each method cannot be determined precisely. However, the number of plants tallied by each method provides an indication of the relative effort required by each method. The point transect method, with 50 points per macroplot, required measurement of an average of 13 shrubs per macroplot. The variable plot method, with one sampling point in the center of each macroplot, required the measurement of an average of 27 shrubs per macroplot. There was an

average of 43 shrubs in or partially in the 15 plots on each macroplot. Using these figures and allowing for the time required to set up the transects, I estimate that the point transect method is about three times faster than the fixed plot method. Since no transects are needed for the variable plot method, it is estimated to be about twice as fast as the fixed plot method.

CONCLUSIONS

Point sampling is faster and more accurate than fixed size plots for estimating production of black sagebrush and Wyoming big sagebrush, according to the results of the field tests. Similar results can be expected with other shrub species with reasonably well defined crowns. In the communities sampled, the point transect method was superior to the variable plot method, but the variable plot method may be better in more arid communities where shrubs are more widely spaced than those in this field test. Meter square plots are probably too small for sampling sagebrush communities. Larger plots would have provided more precise estimates, but would have required even more field time.

The point sampling methods described cannot be applied effectively to estimating production of most herbaceous species. It may be necessary to use plot sampling when the herbaceous component must be estimated. However, fewer and smaller plots would usually be needed to estimate the herbaceous component within a given error limit than would be needed to estimate both the herbaceous and shrub components. A combination of point sampling for shrub production and plot sampling for herbaceous species is probably more efficient than plot sampling alone.

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MUESTREO POR PUNTOS PARA ESTIMAR LA BIOMASA DE ARBUSTOS

Resumen en Español.--Durante casi cincuenta años, se usa muestreo por puntos para estimar las carácteristicas de la vegetación del pastadero, pero no se aplica directamente a la determinación de biomasa de arbustos. Se describen dos métodos de estimar muestreo por puntos. Uno es una adaptación del método de transección por puntos que se usa ordinariamente para estimar la proporción de cubierta vegetal. El otro es una adaptación del método de Bitterlich que hace veintícinco años que usan los forestales para estimar el volumen de madera de construcción. Los dos métodos de muestreo por puntos requiren la determinación de biomasa por cada area de altura de cada arbusto que se cuenta. Este parametro puede ser estimado por regresión con los variables de las alturas medidas.

Se probaron en el campo los dos métodos de estimar muestreo por puntos en communidades de *Artemisia nova* y *A. tridentata wyomingensis* en el oeste de Nevada y se compararon los resultados con un método de parcela de ensayo fija convenciónal. Los resultados de este prueba indican que la técnica de Bitterlich era no solamente el doble en rápidez que la parcela de ensayo fija, pero también el doble en precisión en este tipo de vegetación. El método de transección tenía aun mejores resultados; era tan rápido de tres veces y más preciso de dos y media veces como el método de parcela de ensayo fija. Los dos métodos de muestreo por puntos parecen ser mejor aplicados para muestreo de biomasa y producción en communidades aridos de arbustos.

Using Photo Predictions, Point Sampling and Dendrometry for Timber Volumes[1]

C. R. Chehock[2]

Abstract.--A practical and time-saving procedure is presented for determining timber volumes of large land tracts. The technique employs photo point estimates, point selection and sampling, sample tree selection, and standing tree dendrometry. Field data may be processed by the STXMOD computer program where program flexibility is desired, or hand calculated where it may be most advantageous.

INTRODUCTION

Foresters and land managers are always in need of methods to determine timber volumes of large land tracts with a minimum of time and a high degree of accuracy. With the development of the STX (Sample Tree EXecutive) computer program, this task may be reduced to only a fraction of the time formerly required. The procedure takes advantage of multi-stage sampling, which employs aerial photography, the STX program, 3P (Probability Proportional to Prediction) sampling theory, and standing tree dendrometry.

The following procedures guide users through the necessary steps to perform a multi-stage inventory or cruise, assuming the users have a knowledge of 3P sampling theory, aerial photo interpretation, point sample cruising, field procedures for dendrometry, and the STX computer program. The two sources of variation are characterized by:

1. Variation in ΣD^2H or volume (YL) per acre or hectare, based on the number of KPL's made.

2. Variation in one's ability to predict the point volume or ΣD^2H from a photograph to the actual volume or the ratio of $\frac{YL}{KPL}$

where:

KPL is the photo-interpreter's guess,
YL is the actual value.

The following system provides the greatest accuracy and requires the least time when data is processed with the aid of the STX computer program and the use of 3P sampling. Many of the same principles can be applied if a computer is not available to users; however, if data is hand calculated, there will be some loss of accuracy, program flexibility, and summary tables. Directions for use of hand calculations are included at the end of this report.

PROCESSING WITH STX AND 3P FOR MULTI-STAGE SAMPLING

In forest inventory, the coefficient of variation (CV) of most concern occurs from point to point. This variation is frequently referred to as the physical variation because there is little we can do to change it, except with greater stratification of timbertype mapping, often requiring more time to determine boundaries and acres than it is worth. If the CV is not reduced by type mapping, additional plots or points are required to arrive at an acceptable sampling error (E).

In the past, 400 to 500 ground points or plots were needed to get the sampling error down to ± 4 or 5 percent at one standard error. Using photographs, usually less than 2 years old, and a recommended scale of 1:20,000, points can be located by any desired system, but usually on a grid basis; volume or value predictions are made at each of these points. Because this procedure is done in office, 1,000 or more points can be estimated at a very low cost, thus reducing a major component of the first stage sampling error from ± 4 or 5 percent to only ± 2 or 3 percent or lower, depending on how many points are predicted, and how good the guess is. With training and some ground checking, photo predictions can be made very quickly with adequate accuracy. Photo point predictions are made on the basis of either ΣD^2H or volume per acre or per hectare.

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[1] Paper presented at the Arid Land Resource Inventories workshop, Nov. 30-Dec. 6, 1980, LaPaz, Mexico.
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Sample points are selected for measurement on the ground by comparing the photo-interpreted guess of volume per acre (KPL) at each photo point to a table of random numbers generated by the RN3P computer program.

The number of ground points needed is based on the predictor's ability to make the photoguess and the precision desired. The coefficient of the second stage variation depends on the variation in the ratio of actual point-sampled volume to the photoguess:

$$\text{Ratio} = \frac{\text{actual plot volume}}{\text{photoguess}} = \frac{YL}{KPL}$$

Obviously, this CV cannot be determined until at least one project has been completed or several test points have been predicted for training to establish a person's photoguessing ability. Past projects indicate that most people who have some ground knowledge of the photo area can predict to a CV of less than 20 percent. Based on a CV of 20 percent and 50 ground points, the sampling error for the second stage sample could be about ±2.8 percent.

The 50 points selected from the photographs for measurement are established on the ground as close to the photo-point as possible. These points are usually taken as prism points, but may be by plot if desired. All trees selected by point-sampling are tallied by measured d.b.h. and guessed height. A single sample tree is selected for volume determination at each point with probability HI/ ΣHI where "n" is the number of point-selected trees, and "HI" is the height of the ith tree. At each point, the ratio of each tree is compared to a random number from a list generated from 1 to 100. The first tree encountered on the point having a ratio greater than or equal to a random number is the tree selected for volume determination. The measurements of each sample tree are determined as correctly as possible with standing tree dendrometry to eliminate volume tables and equations for volume determination, thus providing highly accurate volumes, quality and product information.

The relative sampling errors of the two stages may be combined using the following formula to approximate total relative sampling error:

$$E = \sqrt{E_1^2 + E_2^2}$$

The following is the suggested procedure for two-stage sampling using the STX computer program and 3P:

1. List the photo points and their predicted volume per unit area (KPL).

2. Select, with equal probabilities, an adequate number of the points where KPL = 0 to establish ground truth; select with probability proportional to KPL the desired number of samples from points where KPL is greater than zero.

3. Occupy a point on the ground as near as possible to the selected photo-point, and record all point-selected trees

where:

NP = Total number of photo points assigned a KPL (NZ + NT)

a. NZ = number with KPL = 0

NO = number of equiprobable ground point samples selected from the NZ points

b. NT = number with KPL greater than "0"

N1 = number of ground points selected from NT photopoints with PP(KPL)

NE = number of ground points in N1 that were blank (or ΣHI=0)

N2 = (N1-NE) those points where ΣHI is greater than "0".

(Note: "NO" and "N1" are ground-point-sampled to obtain the ΣHI.)

4. One tree is PPS selected with a probability of HI/ΣHI for dendrometry at each "N2" point (all point-selected trees must have d.b.h. and height recorded). All point-selected trees at "NO" points will be dendrometered.

5. Program procedure. The first computer run must include all point-selected trees from points selected by PP(KPL):

a. Punch predicted-only tree cards (column 11 blank) for all point-selected trees of "NO" and "N1" points.

b. Punch KPI, stratum, d.b.h., XTRA (if used for slope and/or slopover) for all point-selected trees.

c. Punch tree and plot number if the tree was selected for dendrometry.

d. All "NO" point-selected trees must be in a separate stratum.

e. Punch XTRB = (NO/NZ)*(ΣKPL/N1) for all trees at "NO" points.

f. Punch XTRB = KPL for all trees at "N1" points.

g. IQ = -100*BAF*(acres/NP) or -1000*METRIC BAF* (Hectares/NP).

h. Options = 1, 1, 0, 0, 0, 0

i. CC3, CC4, CC7, CC8 are all blank.

j. CC6 = ΣKPL/N1

This first run calculates the values to be used on CC3, CC4, CC7, and CC8. The dendrometer cards are then processed in the next run.

6. Dendrometer run procedure. This run excludes all point-selected trees that were not dendrometered.

a. Insert an "=" in column 11 if dendrometered at one of the "NO" points.

b. Insert an "*" in column 11 if dendrometered at one of the "N1" points.

c. If dendrometered at one of the "N1" points (* in column 11), insert in "XTRA" the point ΣHI (if XTRA was used for slope correction and/or slopover; XTRA should be repunched with old XTRA * ΣHI). The appropriate dendrometer cards must follow each tree card.

d. IQ and CC6 will be the same as on the preliminary run.

e. CC3, CC4, CC7 and CC8 will be punched with the data computed by the preliminary run.

f. Options = 2, 2, 3, 0, 0, 0 (the first option must be "2", but the other options may be the choice of the user). The output for the second run will produce the total volume figures for the tract.

PROCEDURE FOR HAND CALCULATIONS

Where hand calculations are preferred or the STX computer program is not available, some sacrifices must be made on the amount of calculating and summarizing that can be done economically. The following procedures show the minimum calculations needed:

1. Establish photo points, and the number of selected sample points, using the same procedure mentioned on the previous page. The predictions, however, should be made in units that are fractions or multiples of the units desired in the final answer. Example: cubic feet per acre, board feet per acre, cords per acre, or cubic meters per hectare, etc.

2. The sample points are also selected for measurement in the same manner as described on the previous page.

3. Rather than measuring the photo point with a prism and standing tree dendrometry, use a fixed area plot and volume tables for all trees on each plot; thus, final volume is calculated in the following way:

$$\frac{\sum^{NP}\text{KPL}}{\text{N1*KPL}} * \frac{\text{YL}}{\text{PS}} * \frac{\text{TA}}{\text{NP}} = \text{Volume represented by "N1" ground plots where KPL is greater than "0".}$$

An adequate number of plots where KPL = 0 should be selected to establish ground truth, using the following formula:

$$\frac{\text{YL}}{\text{PS}} * \frac{\text{TA}}{\text{NP}} * \frac{\text{NZ}}{\text{NO}} = \text{Volume represented by "NO" ground plots where KPL equals "0".}$$

Where:

KPL = Photo point prediction

N1 = Number of points sampled

YL = Measured plot volume

TA = Total area in tract

PS = Ground plot size

NP = Total photo points

NT = Number of photo points with KPL greater than "0"

NZ = Number of photo points with KPL equal to "0"

NO = Number of samples selected from NZ plots

The appropriate choice of formulas above is processed for each sample plot, and the total "volume represented by each plot" becomes the "total tract volume." This procedure may be shortened somewhat by using sums of the ratios shown in the following formula:

$$\frac{\text{TA}}{\text{PS*NP}}\left[\frac{\sum^{NT}\text{KPL}}{\text{N1}} * \sum^{N1}\frac{\text{YL}}{\text{KPL}} + \frac{\text{NZ}}{\text{NO}} * \sum^{NO}\text{YL}\right] = \text{Total volume}$$

A ratio is determined of the YL and KPL for each sampled point, with an average ratio determined for all points. The sum of all KPL's is multiplied by the average ratio and expanded by the acres represented by each KPL point.

SUGGESTED READING

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RESUMEN

Se discute aquí un procedimiento que ahorra tiempo y que es práctico para determinar los volúmenes de madera en grandes predios de terreno. La técnica emplea estimados de punto fotográfico, puntos de selección y muestreo, selección de árbol patrón y dendrometría de árboles en pie. La data de campo puede ser procesada por el programa de computadoras STXMOD cuando se desea un programa flexible, o por cálculos a mano cuando este método sea más ventajoso.

Use of Recreation Opportunity Planning to Inventory Arid Lands in Eastern Oregon - A Demonstration[1]

Michael J. Manfredo and Perry J. Brown[2]

Abstract.--This paper reports on the use of computer and hand drawn techniques for implementing the Recreation Opportunity Planning inventory and analysis phases for the Steens Mountain Recreation Lands. Techniques were compared for land classifications and time and monetary costs. Results show computer mapping less likely to result in classification errors, but more costly to conduct.

The USDI Bureau of Land Management and USDA Forest Service have recently adopted Recreation Opportunity Planning as their primary recreation inventory and evaluation methodology.[3] During its development, Recreation Opportunity Planning has undergone considerable refinement as it has been tried in new situations. One recent refinement of the inventory and analysis phases of Recreation Opportunity Planning has been the development of computer software for storage, retrieval, mapping, and tabulation of recreation resource data (Berry and Brown 1980). This computer program uses the Map Analysis Package (MAP, Tomlin and Berry 1979) and was developed to provide a cost and space efficient alternative to manual production of recreation opportunity maps, to manual preparation of tabular information, and to map overlay data storage. The purpose of this paper is to report findings from a study designed to compare manual and computer technologies in performing the Recreation Opportunity Planning inventory and analysis. In the process of generating data to compare these two technologies, the feasibility of using Recreation Opportunity Planning inventory and analysis on arid lands was demonstrated by applying it to the Steens Mountain Recreation Area in Southeastern Oregon. The objective of this study was to produce recreation opportunity maps by both hand drawn and computer mapping techniques under various information requirements and then compare the time and monetary costs associated with the two techniques.

The Steens Mountain Recreation Area, managed by the Burns District of the USDI Bureau of Land Management, covers approximately 960 square kilometers of a very sparsely populated landscape. The nearest community is about 95 kilometers away.

Steens Mountain is a fault block characterized by steadily rising terrain on its western slope and an abrupt escarpment on its eastern slope. The more accessible western slope offers a variety of recreation opportunities. Prime recreational attractions are several scenic vistas, rugged canyons, good fishing in the major streams and high mountain lakes, developed campgrounds, and many species of game and non-game wildlife. In 1979 the area received 25,535 visitor days[4] of use with fishing, hiking, camping, off-road vehicle use, and hunting as the most popular activities.

RECREATION OPPORTUNITY PLANNING INVENTORY AND ANALYSIS

The inventory and analysis phases of Recreation Opportunity Planning allow the planner to assess an area for its ability to provide recrea-

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[1]Paper presented at the workshop on Arid land resource inventories: Developing cost-efficient methods. LaPaz, Mexico. November 30-December 6, 1980.

The authors wish to thank Dr. J. K. Berry of the School of Forestry and Environmental Studies, Yale University, for his help in making the MAP computer program operational at Oregon State University and Stephen Nofield and Marty Lee for conducting the hand drawn ROP inventory and analysis of Steens Mountain.

[2]Michael J. Manfredo is Assistant Professor and Perry J. Brown is Professor and Head of Resource Recreation Management, Oregon State University, Corvallis, Oregon.

[3]Recreation Opportunity Planning is described in these proceedings in the paper by Brown, P. J., B. L. Driver, and J. K. Berry, "Use of the recreation opportunity planning system to inventory recreation opportunities of arid lands."

[4]A visitor day represents 12 hours of recreation use by one person.

tion opportunities. These opportunities are arranged along a spectrum from modern-urban to primitive. In the most commonly used recreation opportunity inventory and analysis system six different opportunities are identified.[5] These are modern-urban, rural, roaded natural, semi-primitive motorized, semi-primitive non-motorized, and primitive.

In classifying lands for their recreation opportunities three categories of information are used. These are physical, social, and managerial setting. For example, to be classified as providing a primitive recreation opportunity an area must have the physical characteristics of being remote from the sights and sounds of man (about 4.5 kilometers from any road) and being of fairly large size (about 2000 hectares or greater); must have the social characteristic of few encounters among user groups (about two or fewer per day) and have the managerial characteristic of having no recreation facility developments.[6] Using the inventory of these specific recreation setting characteristics, maps can be produced by hand drawing or computer which show potential recreation opportunities based upon physical characteristics, current recreation opportunities based upon physical, social, and managerial characteristics, and changes in recreation opportunities provided due to changes in physical, social or managerial characteristics.

Mapping by hand drawing requires an individual to prepare overlays for each setting characteristic, to overlay the setting characteristic maps, and to delineate recreation opportunities based upon the criteria established. After recreation opportunity areas are delineated, a planimeter or other area measurement device can be used to calculate the amount of land providing each recreation opportunity.

Computer mapping requires an individual to prepare a map for each setting characteristic and to digitize it into a computer ready format. These data are read using the MAP computer program which adapts the digitized data to a grid-cell format. The planner then develops recreation opportunity maps and tabular summaries by combining and modifying the base maps through a series of analytic operations available in the MAP package. A general model for conducting the inventory is presented in Berry and Brown (1980), but the specific analytic operations necessary should depend on the planning situation. Analysis can be performed from remote job entry terminals or by submitting cards.

In conducting the inventory and analysis for the Steens Mountain Area, information was obtained from discussion with managers, topographic maps, and aerial photographs. The inventory required complete information on the existing road system, trails and other transportation features, irreversible evidences of man (e.g. reservoirs, mines, etc.), renewable resource modifications (e.g. livestock grazing), recreation user densities and contact levels, and types and locations of recreation management activities. Individuals trained in both manual and computer techniques performed the inventory and analysis. Records of time and monetary costs were kept. All hand mapping was performed using 7.5 minute USGS topographic maps and acetate overlays. Resource data were digitized using a model GP 6-4 Sonic Digitizer and a 4051 Tektronix Computer was used to convert coordinates to the Universal Transverse Mercator System. All subsequent computer analyses of data were performed on a CDC-CYBER 173 computer at Oregon State University.

RESULTS

Since the Steens Mountain Recreation Area is not characterized by extensive facility development, high user densities, or diverse and extensive renewable resource modification, the recreation opportunity inventory was relatively simple to perform. The most important criteria for classifying the area's recreation opportunities were remoteness and size of area.

Figures 1 and 2 show the Steens Mountain Recreation Area zoned for the type and distribution of recreation opportunities it currently provides. Figure 1 was hand drawn and Figure 2 was computer produced. These maps are quite similar, as they should be. Most of the area offers a semi-primitive motorized (SPM) form of recreation with about 60 percent of the more than 108,000 hectares inventoried offering this type of recreation (table 1). About one quarter of the area provides a semi-primitive non-motorized type of opportunity (SPNM) while the remainder of the area provides a roaded natural (RN) type of opportunity.

Both technologies for producing the recreation opportunity map detected a band of area providing roaded natural opportunities looping into the area from west to east. This coincides with the main access road into the area. The rugged east slope of the area which is largely inaccessible and most of the canyon and gorge areas were zoned as providing semi-primitive non-motorized recreation opportunities. The remainder of the area which is criss crossed with jeep trails and secondary roads was identified as providing semi-primitive motorized opportunities.

Although there was considerable similarity between figures 1 and 2, there were some differences. Particularly noticable on the hand drawn map was the absence of the large SPNM zone just north of the RN loop. Additional differences, of considerably less magnitude, can be found between the maps. Only about two percent of the total area was classified differently using the two techniques (table 1). There was two percent more SPNM area on the hand drawn map and one percent more each of SPN and RN on the computer map.

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[5]Greater and fewer types of opportunity have been used when special needs have arisen.

[6]Other criteria and their standards will be forthcoming in Chapter 500 of the USDA Forest Service Land Management Planning Handbook (FSH 1909.12).

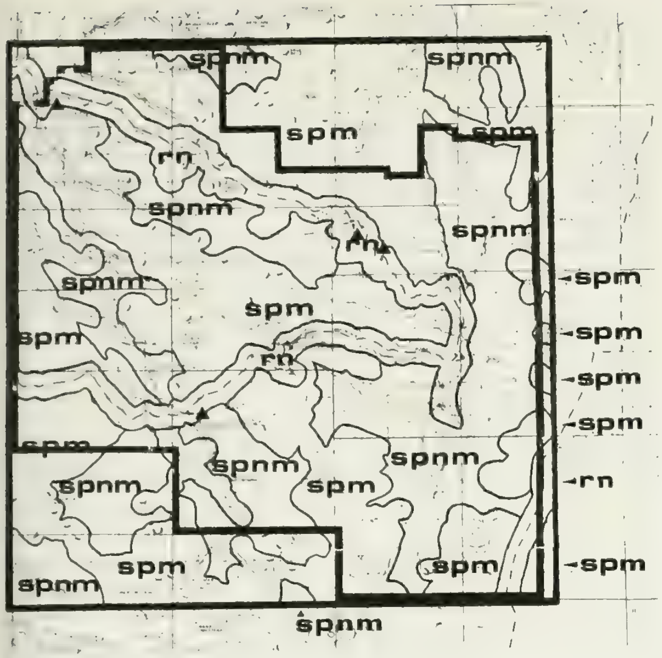

Figure 1.--Hand drawn recreation opportunity areas of Steens Mountain. Recreation opportunities shown are RN, roaded natural; SPM, semi-primitive motorized; and SPNM, semi-primitive non-motorized. The outside dark heavy line denotes the demonstration area boundary while the inside line is the legally defined Steens Mountain Recreation Lands.

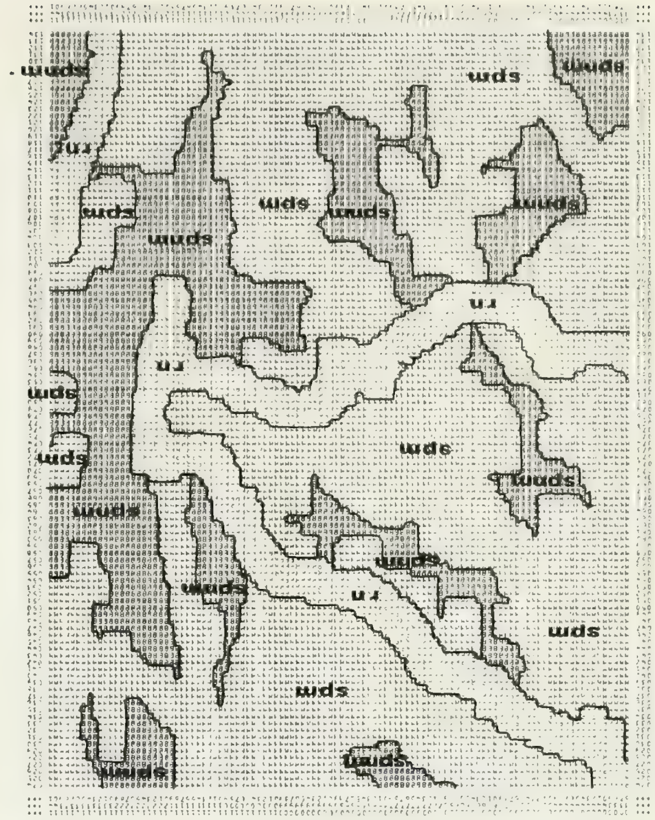

Figure 2.--Computer drawn recreation opportunity areas of Steens Mountain. Recreation opportunities shown are RN, roaded natural; SPM, semi-primitive motorized; and SPNM, semi-primitive non-motorized.

Since differences are apparent between maps the obvious question is which map is correct? Since the maps are very similar if the large SPNM area omitted from the hand drawn map is added, either map might be considered as acceptable. Most of the differences in zoning were due to either (1) making judgments about lands along the borders between two classes, and (2) lack of precision in computer mapping resulting from the size of the grid-cells (about 9 hectares).

Once managers have information on current recreation opportunities they might ask how opportunities will change in response to specific management actions. This is the case in the Steens Mountain Recreation Area where managers have proposed closure of some roads. We assessed the effect of these closures by remapping the area assuming road closures were in effect and comparing this map to the original map. Figures 3 and 4 are the new maps considering the road closures. There is considerable similarity between these maps. Differences which exist can be seen by comparing figures 5 and 6, which show only the changes in classification from the original maps (figures 1 and 2).

The primary effect of the road closures was an increase in semi-primitive non-motorized recreation at the expense of semi-primitive motorized recreation (table 2). The computer technique shows an SPNM increase of about 6 percent while for the hand

Table 1.--Comparison between computer and hand drawn recreation opportunity areas.

Type of	Hand Drawn Technique		Computer Technique	
Opportunity	Hectares	Percent	Hectares	Percent
Semi-Primitive Non-Motorized	28,679	26.9	26,771	25.2
Semi-Primitive Motorized	62,605	58.8	63,601	59.9
Roaded Natural	15,166	14.3	15,789	14.9
	106,450	100	106,161	100

Table 2.--Comparison between computer and hand drawn recreation opportunity areas after road closure for Steens Mountain.

Type of Opportunity	Hand Drawn Technique Hectares	Hand Drawn Technique Percent	Computer Technique Hectares	Computer Technique Percent
Semi-Primitive Non-Motorized	36,345	34.1	33,285	31.4
Semi-Primitive Motorized	55,577	52.2	56,049	52.8
Roaded Natural	14,528	13.7	16,827	15.8
	106,450	100	106,161	100

Table 3.--Comparison of net change in area for computer and hand drawn recreation opportunity areas due to proposed road closures.

Type of Opportunity	Hand Drawn Changes in Classifications Hectares	Hand Drawn Changes in Classifications Percent	Computer Changes in Classifications Hectares	Computer Changes in Classifications Percent
Semi-Primitive Non-Motorized	7666	7.2	6514	6.1
Semi-Primitive Motorized	-7028	6.6	-7552	7.1
Roaded Natural	- 638	0.6	1038	1.0

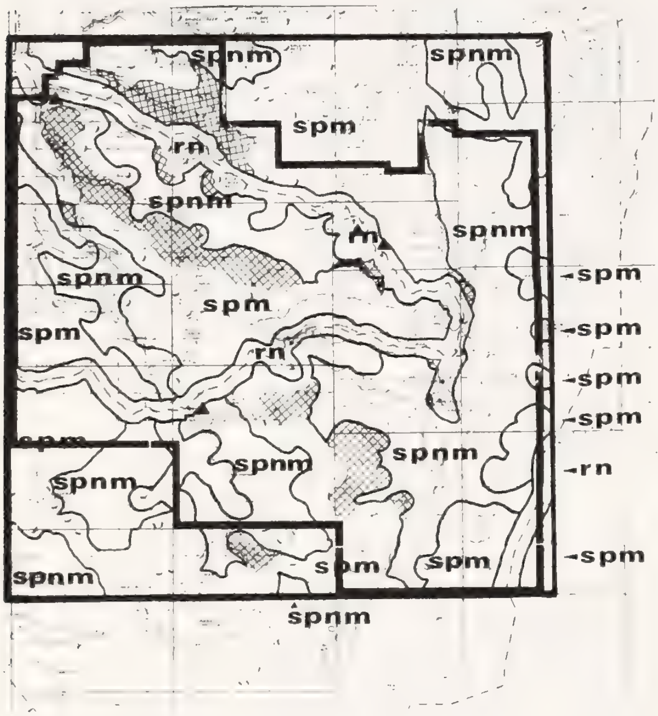

Figure 3.--Hand drawn recreation opportunity areas of Steens Mountain assuming proposed road closures. Recreation opportunities shown are RN, roaded natural; SPM, semi-primitive motorized; and SPNM, semi-primitive non-motorized. The outside dark heavy line denotes the demonstration area boundary while the inside line is the legally defined Steens Mountain Recreation Lands. Hatched areas are areas which changed from their initial classification (figure 1).

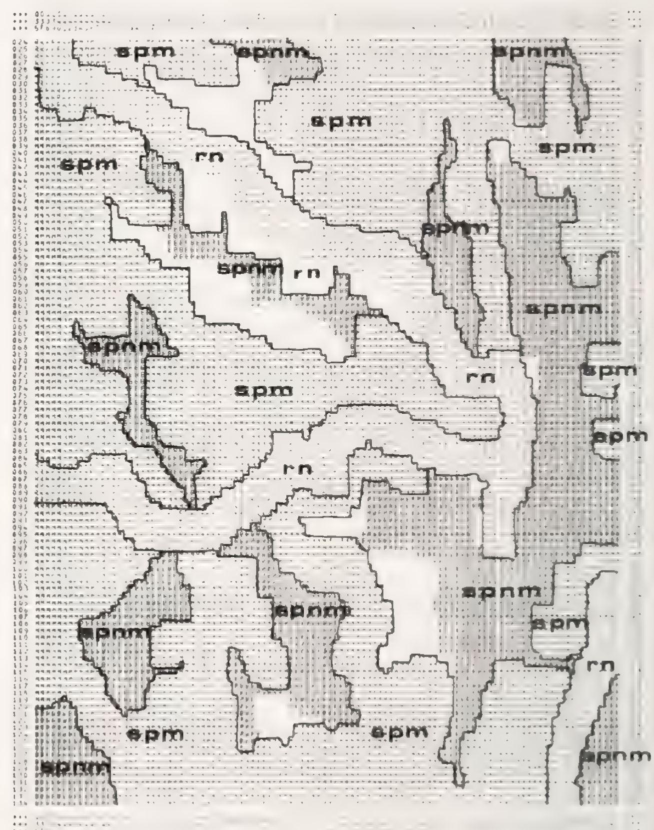

Figure 4.--Computer drawn recreation opportunity areas of Steens Mountain assuming proposed road closures. Recreation opportunities shown are RN, roaded natural; SPM, semi-primitive motorized; and SPNM, semi-primitive non-motorized. White areas within the map boundaries are areas which changed from their initial classification (figure 2).

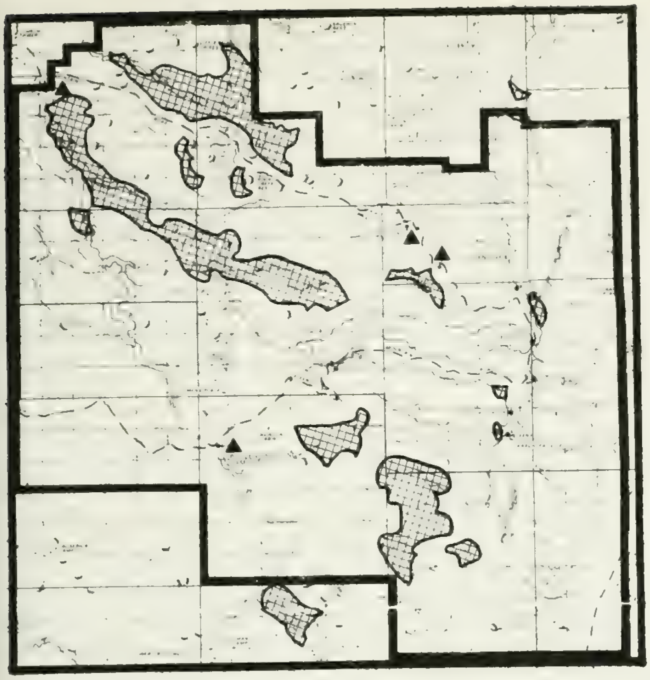

Figure 5.--Hand drawn areas which changed from their initial classification (figure 1) due to proposed road closures. Recreation opportunities shown are RN, roaded natural; SPM, semi-primitive motorized; and SPNM, semi-primitive non-motorized. The outside dark heavy line denotes the demonstration area boundary while the inside line is the legally defined Steens Mountain Recreation Lands. All changes resulted in additions to the SPNM class.

drawn map technique it was 7 percent (table 3). The biggest difference between the techniques was in indicating the effect on roaded natural opportunities. Computer estimates indicated a 1.0 percent increase while the hand drawn map technique produced a .6 percent decrease. Since each estimate of impact was based on original maps which were slightly different, these differences were understandable.

The time and monetary costs invested in producing the recreation opportunity maps for the Steens Mountain Recreation Area are shown in table 4. In considering these values one should keep in mind that they are specific to the Steens Mountain case and might not be applicable to other mapping situations. These data indicate that the computer technology took less time than hand drawn mapping but cost considerably more. The labor costs were actually less for the computer method but the costs of digitizing and preparing an error free data base were substantial.

The time and monetary costs for revising the maps to consider the proposed road closures are shown in table 5. The time involved in the computer technique again was less while the monetary

Figure 6.--Computer drawn areas which changed from their initial classification (figure 2) due to proposed road closures. Recreation opportunities shown are RN, roaded natural; SPM, semi-primitive motorized; and SPNM, semi-primitive non-motorized. All changes except three small changes, resulted in additions to the SPNM class.

costs of the computer technique were substantially higher than the hand drawn mapping technique. In this case the actual computer map development was much more costly than such tasks as digitizing and base data revision.

CONCLUSION

Our involvement in conducting the recreation opportunity inventory and analysis for the Steens Mountain Recreation Area leads us to conclude that Recreation Opportunity Planning can be easily adapted to arid land situations. Our work indicates that recreation opportunity mapping of arid lands is tenable using either computer or hand mapping techniques and that the time and costs involved would not be deemed excessive.

Managers can expect different results when using computer and hand mapping techniques for Recreation Opportunity Planning inventory and analysis. It seems likely that the tedium of hand mapping leads to mistakes in classification of

Table 4.--Comparison of time and monetary costs associated with computer and hand drawn techniques for performing Recreation Opportunity Planning inventory and analysis.

	Costs		
Technique	Materials/ Operations	Labor	Time (hours:minutes)
COMPUTER MAPPING TECHNIQUE			
Digitizing	$ 88.00	$ 59.00[1]	12:15
Base Data Set Up	54.50	23.00[1]	4:45
Map Development	44.50	16.00[2]	3:00
Data Storage	8.50		
Sub Totals	195.50	98.00	
TOTAL	$293.50		20:00
HAND MAPPING TECHNIQUE			
Materials	34.50		
Labor Zoning		63.50[2]	11:45
Measuring		67.50[1]	14:00
Sub Totals	34.50	131.00	
TOTAL	$165.50		25:45

[1]Based on U. S. Government 1980 GS-4 Wage Rate

[2]Based on U. S. Government 1980 GS-5 Wage Rate

Table 5.--Comparison of time and monetary costs associated with computer and hand mapping techniques of assessing impacts of road closures.

	Costs		
Techniques	Materials/ Operations	Labor	Time (hours:minutes)
COMPUTER MAPPING TECHNIQUE			
Digitizing	$ 22.50	$ 23.00[1]	4:45
Base Data Revision	10.00	8.00[2]	1:30
Map Development	45.50	11.00[2]	2:00
Data Storage	8.50		
Map Comparisons	16.50	8.00[2]	1:30
Sub Totals	103.00	50.00	
TOTAL	$153.00		9:45
HAND MAPPING TECHNIQUE			
Materials	13.00		
Labor Zoning		35.00[2]	6:30
Measuring		28.50[2]	5:15
Sub Totals	13.00	63.50	
TOTAL	$ 76.50		11:45

[1]Based on U. S. Government 1980 GS-4 Wage Rate

[2]Based on U. S. Government 1980 GS-5 Wage Rate

areas or in their measurement. On the other hand, hand mapping is superior for cases where classification of an area might be done outside rigid specification of criteria, as when evaluations are made using personal knowledge of onsite conditions.

Computer mapping is advantageous in that it is highly improbable that errors will be made in measurement or in implementing criteria. However, the lack of precision in computer mapping will undoubtedly result in some error in estimating sizes of areas. Additionally, injecting judgments into the classification process, although possible, is not as easily accomplished as with the hand mapping technique.

The time and monetary costs involved in computer mapping do not justify its use as a substitute for hand mapping techniques. However, we found that about one half the cost of the computer technique was attributable to setting up the data base. If that expense were eliminated, there would be little difference in the cost of computer versus hand mapping. Therefore, if managers are currently using computer mapping analysis of their resources, and have base data digitized or by grid-cell, it might be advantageous to use the computer technique.

Since neither technique could be labeled totally error free, it is our conclusion that Recreation Opportunity Planning inventory and analysis would be made more accurate using a combination of computer and hand mapping technologies. Recreation Opportunity Planning maps could be produced on computer based systems and serve as base maps which could be further modified based on other criteria and judgments. In this way Recreation Opportunity Planning classifications would be made with accurate implementation of classification criteria while allowing easy, and cost effective, modification of maps.

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RESUMEN

En este artículo se informa el uso de la computadora y de las técnicas de dibujo a mano para implementar el inventario de Planificación de Oportunidades Recreativas y las fases de análisis para las Tierras Recreativas en las Montañas Steens. Las técnicas fueron comparadas en cuanto a clasificación de tierras,y costos monetarios y de tiempo. Los resultados demuestran que habría menos errores de clasificación si se utiliza la cartografía por computadora, pero que este método resultaría más costoso.

Phytosociological Inventory as a Basis for Resource Evaluation in Arid Lands[1]

Marinus J.A. Werger[2]

Abstract.--A phytosociological inventory of the vegetation of an area allows to classify the vegetation in ecologically and floristically characterized units at various levels of generalization. It thus provides an excellent basis for the preparation of vegetation and land units maps at various scales. The phytosociological classification shows the principal floristic relationships between the types and allows a detailed estimate of the floristic variation between stands and between types. Combination of the results of a phytosociological classification and knowledge about (a) the standing crop of some key areas, (b) the nutritive value of key species (c) and the three main modes of photosynthesis (C_3,C_4, CAM), allows an asessments of grazing resources or an evaluation of ecological features of an area. This application is demonstrated on a very long transect study straight through the arid Karoo-Namib Region of southern Africa.

INTRODUCTION

Effective usage of vegetation resources of dry areas implies avoidance of overgrazing and destruction of the vegetation beyond recovery. Such destruction nearly irreversibly leads to undesired developments like the invasion or increase of unpalatable or poisonous species, the temporary establishment of a few annual species and subsequent bare soil surfaces, or denudation and soil erosion leaving useless waste areas. Effective usage implies, however, a management program based on the natural entities of the area at the level of the ecosystem. Recognition of these entities, the ecosystems, and some knowledge of their functioning as regards their structure and the functional relations between the biotic and abiotic components of the system, are a necessary precondition for such a management program. Such knowledge should result in the recognition of ecologically meaningful and mappable units. As plants are excellent indicators of environmental factors, and vegetation forms an integral and characteristic part of terrestrial ecosystems, also in arid areas, the ecologically relevant mappable units of an area can be delimited accurately by their plant communities (see Werger 1977 for further references).

PHYTOSOCIOLOGICAL INVENTORY

Identification of natural entities by recognition of plant communities should be based on characters of the vegetation itself, and thus should use structural-functional criteria or floristic criteria. Structural-functional criteria are as yet relatively difficult to define precisely and therefore, difficult to quantify, as compared to floristic criteria. Besides, application of structural-functional criteria virtually always implies the need for a range of technical equipment if a somewhat more sophisticated stage of insight than gross superficiality is wanted, whereas application of floristic criteria requires a good floristic knowledge only. Moreover such floristic knowledge usually is also desirable when structural-functional criteria are used, since one often wants to know to which species the measured characteristics apply. On the other hand, measurements of structural characteristics and performances of species using advanced instrumentation is usually wanted as a follow-up of a floristic inventory of various vegetation types of an area. However, after a proper delimitation of the plant communities of an area, such measurements can justifiably be restricted to certain key species which are not necessarily the dominants.

It is important to keep in mind that plant species are good indicators of habitat factors. Thus, as ecological amplitudes of the species become known, accurate characterization of the most deci-

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[1]Paper presented at the International Workshop on Arid Land Resource Inventories: Developing cost-efficient methods, La Paz, Mexico, November 30 - December 6, 1980.

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sive habitat factors for plant growth at any site is possible on the basis of its species content. For an initial delimitation and recognition of the plant communities of an area (and thus of the ecological entities in an area) reaching a satisfying degree of precision, and for a fruitful further use of these inventory data in follow-up ecological work, the use of floristic criteria, preferably the total floristic composition of a site, seems to be an appropriate and efficient tool.

Floristic characterization of the units of an area always implies a hierarchical classification at various levels of similarity. These results from the ecological amplitudes of species which are usually different in widths, so that the ecological, and thus floristic boundaries in an area usually are constitued by coincidences of only parts of the distributional requirements of the species in that area.

Floristic classification and characterization requires sampling of plots of sufficient size to provide a representative description of the vegetation in the stands. Usually this means plots of several square meters. Another precondition is that the plots internally should be more or less homogeneous in floristic composition and environmental features, so that each plot sample refers to only one kind of stand and not to a mixture of more than one kind of stand. Sampling can be accomplished by systematic, random, stratified random, or representative distribution of plots. Systematic and random sampling have the disadvantages of being inefficient in that certain kinds of stands may be undersampled while others are oversampled, and in frequently producing sample plots which do not meet the criterion of homogeneity. Stratified random and representative sampling strategies generally prevent these shortcomings, but representative sampling is certainly the most efficient strategy of the two.

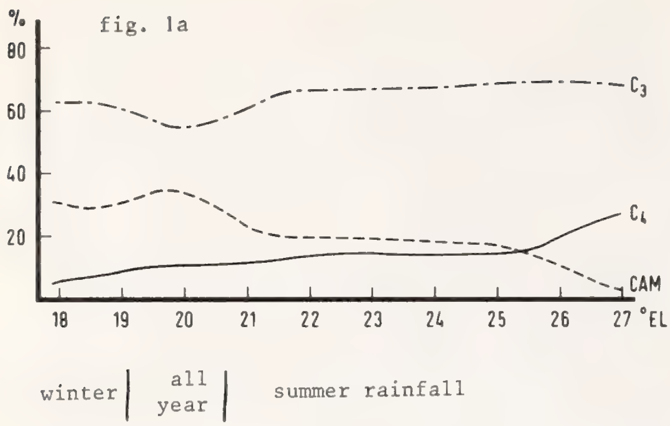
After having sampled a sufficiently large number of plots, covering the total variety of kinds of vegetation stands in an area, the plot data are classified by means of a table technique or a cluster analysis. Both classificatory processes usually lead to compatible results (see e.g. Coetzee and Werger 1975).

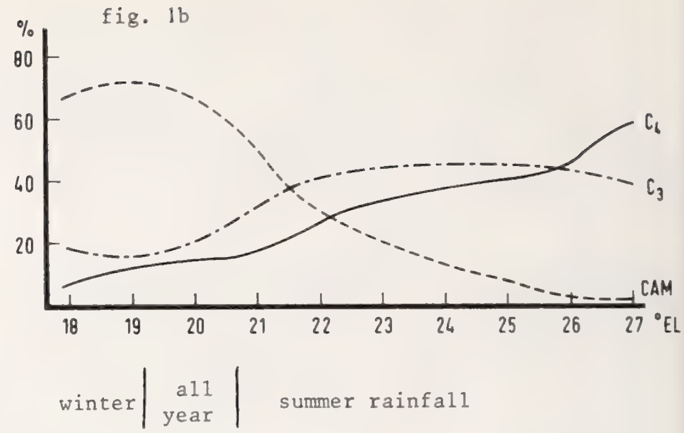
These classificatory techniques produce a hierarchical classification of vegetation types, the types being distinguished from one another by differential species. Such differential species need not be dominants; they are species with relatively narrow ecological amplitudes in the area studied. They are, therefore, good indicators of the complexes of ecological factors which determine the pattern in the distribution of the species and consequently determine the pattern of the plant communities. Moreover, because the abundance of each species at any site is determined by its ecological amplitude and the site conditions, such a hierarchical classification of plant communities based on floristic composition not only reflects the floristic interrelationships of the communities, but at the same time the ecological ones.

Various classificatory techniques are described in a number of modern handbooks on vegetation science, for example by Whittaker (1973) and Ellenberg and Mueller-Dombois (1974). The advantages of the phytosociological table technique have been discussed in detail with a number of examples by Werger (1977). These advantages amount to the following: (1) the floristic characterization of each community and the floristic interrelationships between communities is seen at a glance; (2) abstraction at various levels of the hierarchy is possible, and thus allows mapping at various levels of generalization which may be necessary for mapping at various scales; (3) the variation in species composition in stands belonging to the same community is immediately apparent; (4) the overall importance of each species in each community is shown, together with the variability in importance between the various stands of the community; (5) because the overall floristic composition of a community and the overall importance of a species in a community is shown, the table pattern suggests conclusions about the possibly degenerated status of a deviating stand belonging to the community type; (6) similarly, the occurrence of stands which are transitional in floristic composition, and thus presumably also in ecological characteristics, is easily discerned.

ECOLOGICAL EVALUATION OF THE PHYTOSOCIOLOGICAL INVENTORY

The amount of detailed floristic information contained in a phytosociological inventory and the general features of the plant communities shown at the same time by such a properly analysed inventory of phytosociological data, allows an ecological evaluation of the plant communities along several lines. Phytosociological analysis allows the selection of those species which most strikingly differentiate between communities and apparently indicate differences in the ecological factors operating at the various sites. Experimental ecological research should be aimed at those species, since knowledge of the ecology of those species, most efficiently contributes to knowledge about the ecology of the communities for which they are indicative. Phytosociological analysis also allows the selection of key species which are most characteristic for a community or group of communities in terms of biomass or cover; it is clear that in arid range lands such species may be of particular interest for further study on their palatibility, nutritive value, and regeneration potential following grazing. By determining the average size or weight of individuals of these species, and combining these data with the phytosociological data, the density or standing crop of these species in some key areas is easily calculated. On the basis of a map of the phytosociologically delimited plant communities of a region, overall data on phytomass of these species in the region can be obtained, as well as more differentiated information on variation in distribution of these species over the region. Using this information, and combining it with knowledge about the grazing potential of such species (palatability, nutritive value, regrowth)





the carrying capacity of the various plant communities can be determined. Once this is known, an efficient management program for grazing resources in which differences in carrying capacity between the communities, and the pattern of distribution of the various communities over a region are taken into account, can be drawn up.

In a similar way other ecological features of the vegetation of a region may be evaluated. Fig. 1a + b, for example, shows the importance of the three main modes of photosynthesis (C_3, C_4 and CAM) for various parts of the arid Karoo-Namib region in southern Africa. The figure is based on phytosociological data sampled along a long West-East transect of nine degrees of longitude taken at about 30°30' Southern Latitude straight through the dry region from the Atlantic coast to the semiarid grassland area in the interior of South Africa. Along this transect the climatic changes from a moderately hot, very dry winter rainfall climate with frequent fog, to a hot and dry all year rainfall climate and a hot and dry summer rainfall climate which gradually becomes more temperate and more moist in eastern direction. Fig. 1a shows the importance of the three modes of carbon gain strategy in terms of species present in the flora at a dozen sites along the transect; Fig. 1b shows the same based on the relative importance of these species in the vegetation at each site in terms of canopy cover. It is clear that whereas C_3 species are far more numerous throughout the entire area, the C_3 mode of photosynthesis only achieves predominance in the summer rainfall part of arid South Africa as well as in a very narrow coastal belt. In the winter rainfall and all year rainfall parts of arid South Africa the CAM mode of photosynthesis is by far most prominent in the vegetation; it gradually decreases in the summer rainfall area even though the number of CAM species present in the local floras diminishes very little until the dry and hot parts of the summer rainfall area are reached, where night frosts are common in the winter season. There C_4 species become more numerous but the importance of this way of carbondioxide fixation in the vegetation has already increased strongly at the transition from all year to summer rainfall area in accordance with a high air temperature during the growing season there (Werger and Ellis 1980).

Owing to the detailed floristic analysis of the vegetation various other ecological characteristics of the flora and vegetation can be evaluated using these same data, provided that such ecological knowledge about all or the most important species is known. Thus, a phytosociological analysis of the vegetation provides a sound base for a versatile approach to evaluate various ecological features of the vegetation of an area so that a meaningful pattern may be obtained.

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RESUMEN

Un inventario fitosociológico de la vegetación en un área específica permite la clasificación de la vegetación en unidades ecológicas y florísticas en varios niveles de generalización. De esa forma provee una base excelente para la preparación de mapas unitarios de la vegetación y tierra en escalas variadas. La clasificación fitosociológica demuestra las principales relaciones florísticas entre los tipos, y permite un estimado detallado de las variaciones florísticas entre rodales y tipos. La combinación de los resultados de una clasificación fitosociológica con la data conocida acerca de (a) la cosecha en pie en áreas claves, (b) el valor nutritivo de especies claves, y (c) los tres métodos principales de fotosíntesis (C_3, C_4, CAM) permiten la evaluación de los recursos de pastoreo o una evaluación de las características ecológicas de un área. Este método ha sido utilizado en un estudio transeccional de larga duración directamente a través de la región árida Karoo-Namib en el sur de Africa.

Esquemas de Muestreo Aleatorio para el Estudio de Poblaciones Naturales de "Candelilla" (Euphorbia antisiphylitica).[1]

Sergio Arnoldo Ortega[2]

La mayoría de los desiertos, que se localizan en el Globo terraqueo, han presentado diferencias en cuanto a su formación, clima, suelo, - vegetación, etc., pero en todos ellos se han podido observar, una marcada escasez de precipitaciones pluviales.

En México, la formación de los desiertos se debe a la presencia de mecizos montañosos, que impidiendo el paso de los vientos humedos contribuyen a la formación de la "Sombra Orográfica" o "Sombra de Lluvia", tal es el caso del desierto Chihuahuense; o debido a la presencia de corrientes maritimas frias que azotan las Costas de Baja California Norte y Sur, así como parte de Sonora, formando el desierto Sonorense.

Las Zonas Aridas y Semi-áridas, ocupan en la República Mexicana alrededor de 90,000,000 de hectáreas (aproximadamente el 40.5%) y se encuentran distribuidas en el Norte del País, cubriendo parte de los Estados de Baja California Norte y Sur, Sonora, Chihuahua, Durango, Zacatecas, -- San Luis Potosí, Nuevo León, Tamaulipas, Querétaro, Hidalgo, Puebla y Oaxaca.

Una de las características principales de los desiertos es el clima tan extremoso, pero a - pesar de dicho factor físico adverso para la sobrevivencia, la selección natural ha dejado en dichas regiones, plantas y animales peculiares que - por variados y fascinantes artificios biologicos han resuelto el problema de la sobrevivencia en un medio inhospito; tal es el caso de la candelilla, que llegando la época seca, cierra sus estomas y empieza a"sudar cera", utilizando esto como una defensa, cubriendose totalmente evitando así la evaporación; por medio de este mecanismo, dicha planta puede soportar facilmente varios meses de - sequía.

La Candelilla es una planta típica del desierto Chihuahuense que se distribuye en el Norte de la República Mexicana en los Estados de Coahuila, Chihuahua, Durango, Zacatecas, Nuevo León, -- San Luis Potosí y Tamaulipas, cubriendo una superficie aproximada a los 14 millones de hectáreas; superficie que en ultimas fechas a disminuido - - considerablemente debido al método tradicional de explotación durante su recolección, el cual consiste extraer la planta con todo y raíz, siendo este un método destructivo que se ha utilizado desde -- los inicios en que se empezó a explotar la candelilla, lo que ha traído como consecuencia que en la actualidad sea una de las especies más amenazadas con extinguirse, debido a la infinidad de usos que tiene la cera que de ella se obtiene, ya que - la demanda de dicho producto se ha incrementado en forma considerable.

CLASIFICACION TAXONOMICA:

DIVISION	Spermatophyta
CLASE	Angiospermae
SUBCLASE	Dicotyledoneae
ORDEN	Euphorbiales
FAMILIA	Euphorbiaceae
GENERO	Euphorbia
ESPECIE	Antisyphillitica

DESCRIPCION BOTANICA:

RAIZ.- Presenta gran cantidad de raicillas adventicias, dando el aspecto de una cabellera -- (en una planta adulta). Las raicillas son muy -- delgadas, bastante largas y nacen por grupos en - diferentes partes del rizoma; ocasionalmente nacen aisladas y se ramifican poco después de su nacimiento.

TALLO.- La planta presenta tallos aereos y subterráneos, el tallo áereo presenta a simple vista el aspecto de una vara, cilindrica, lampiña y de color verde glauco, debido a que esta cubierto de una capa de cera. Su ramificación es simpódica. Los renuevos son de color verde palido, aunque en algunos tramos presenta tintes rojizos. Los tallos forman macollas, teniendo un desarrollo, el cual - varia de 20 a 80 cm., de altura. Siendo en estos - tallos en donde se localizan los poros ceriferos.

La planta posee un tallo subterráneo principal, grueso y de color cafe más oscuro que el resto, del que nacen tallos más delgados que se dirigen hacía arriba y emergen a la superficie de la

[1] Trabajo presentado en el Evento Internacional, "Inventarios de Recursos de Zonas Aridas", La Paz, B.C.S., Mexico, Nov. 30 - Dic. 6, 1980.

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tierra. El tallo principal es un rizoma, solo que no toma necesariamente la posición horizontal, característica de los tallos aereos, sino que pueden ser verticales, inclinado y en algunos casos horizontal.

HOJAS.- Son esparcidas, sesiles y pequeñas, sobrepesado escasamente en su mayoría 1 mm, de longitud y de 1 a 2 mm, de ancho. Son de color totalmente verde, las que se encuentran en el extremo distal del tallo que por lo general son 2 o 3; el resto de ellas, considerándolas desde la parte superior del tallo a la inferior, presentan un tinte rojizo que comienza en el apice y continua por los bordes, avanzando hacía el centro del limbo a medida que se trata de hojas adultas hasta que finalmente se desprende la hoja, en el caso de que los renuevos presenten coloración rojiza, todas sus hojas, inclusive las más jóvenes son totalmente rojas.

FLOR.- La inflorescencia de la candelilla es comunmente una espiga de cabezuelas, las flores de ambos sexos se encuentran dentro de una estructura en forma de copa llamada CIATO, conteniendo cada una aproximadamente de 45 a 47 flores masculinas y una femenina en el centro, la cual no siempre se desarrolla. Generalmente cada espiga consta de tres cabezuelas, una de las cuales frecuentemente no alcanza su total desarrollo. En algunos casos la inflorescencia no adopta la disposición de espiga, sino que sobre un mismo punto nacen 2 o 3 ciatos.

FRUTO.- Es una cápsula trilocular que pende un largo pedunculo, el ginofero. Cuando llega a su madurez toma una coloración cafe de tonalidad variable. Cuando los ovulos han completado su desarrollo y se transforman en semillas, la cápsula estalla arrojando a estas en torno de la planta; siendo esta una forma de reproducción natural.

La recolección de la semilla es muy díficil debido a la fenología de la planta y al tamaño de la misma; pero se ha podido determinar que un kilogramo contiene alrededor de 272,000 semillas con aproximadamente un 80% de S.P.V.

LACTICIFEROS.- Se encuentran en la región del periciclo, en la endodermis y en la corteza media así como entre los haces liberianos, siendo mas abundantes en la región del periciclo y en los espacios que hay entre dichos haces. Estos conductos son de los llamados articulados, anastomosados y ramificados. Por su interior circula un latex de color blanco y pegajoso que se coagula al contacto del aire.

HISTORIA.- El Botanico Zuccarini en 1829 dio el nombre de Euphorbia antisyphillitica a la planta mexicana, hoy en día la fuente principal de cera; la descripción de Zuccarini es breve pero tan exacta como lo indica. A partir de este siglo, la candelilla fue dada a conocer como la fuente potencial de la cera dura, aunque su desarrollo como un producto comercial no fue reconocido hasta 1939. En 1909 alcocer llamó a la planta de candelillas Euphorbia cerifera, y dio una descripción botánica completa e ilustración, también como el amplio cálculo de la cera dura. La planta descrita por Alcocer, no es separable de la descrita por Zuccarini sobre las bases de su diagnosos publicada y porque Alcocer ha observado el nombre de su Euphorbia cerifera como un sinónimo de Euphorbia antisyphillitica Zucc.

La primera nota a nivel científico sobre candelilla, apareció en 1910 en una publicación anónima de "La Real Sociedad de Artes de la Gran Bretaña", destacando sus propiedades medicinales.

Se tiene conocimiento de que en 1905. Mc Connekk y Landeres realizarón trabajos sobre la composición, blanqueo y propiedades físicas y químicas de la cera.

En el año de 1910 en Nuevo México, se realiza la primera operación a escala piloto de que se tiene noticia, empleando agua caliente para la extracción de la cera. Por el año de 1913, se inició la industria de la cera de candelilla en las ciudades de Monterrey, N. L. y Torreón, Coahuila, el método que se utilizaba era a base de vapor de agua a presión, para disolver la cera, separando esta de los tallos e impurezas por decantación en 1914 los señores Borrego y Flores, diseñaron el método que actualmente se emplea; el cual consiste en sumergir la hierba de candelilla en agua en ebullición, añadiendóle aproximadamente un 8% de ácido sulfurico en base al peso de la planta en verde. El citado metodo de extraccion de cera, es el ya tradicional desde su inicio de explotación hasta la fecha.

HABITAT.- La candelilla generalmente se encuentra en suelos calcareos, de origen coluvial, de profundidad somera (menor de 25 cm.), de textura franco arenosa, estructura granular, de consistencia friable, con presencia de pedregosidad y con un pH que fluctua entre 7.0 y 7.4

El clima que prefiere de acuerdo a la clasificación de Koopen y adaptada a la República Mexicana por Enriqueta García; es el BW (muy árido con lluvias en verano), donde existe una precipitación pluvial promedio que varia de 120 mm al año; una tempertura media anual de 18 a 22° C, resistiendo temperaturas maximas de 47° C y minimas hasta de 14° bajo cero; las alturas sobre el nivel del mar en que se encuentra estan situadas de 250 a 1400.

La candelilla se encuentra dentro del tipo de vegetación denominado natorral crasirosulifolio espinoso, asociada con otras especies como son: Lechuguilla Agave lecheguilla (que es la especie dominante dentro de este tipo de vegetación), Guapilla China Hechtia glomerata, Sotol Dasylirion berlandieri y Espadin Agave falcata; en algunas ocasiones se encuentra formando parte del matorral inerme parvifolio, asociada principalmente con Gobernadora Larrea tridentata (especie dominante de dicha comunidad vegetal); otras veces es localizada dentro del bosque oligocilindrocaule rosulifolio, asociada con Palma samandoca Yucca carnerosana (que es la especie dominante).

Analizando las características ecologicas descritas anteriormente, se observa que la candelilla prospera en condiciones de clima y suelo extremadamente raquiticos, condiciones por demás inadecuadas para efectuar explotaciones agrícolas que son más exigentes en cuanto a suelo y agua se refiere.

USOS DE LA CERA.- Comparando la cera de candelilla con otras ceras, resulta más dura y menos quebradiza que la de Carnauba, aunque fundida es más viscosa que ésta. Iguales propiedades presenta con relación a la cera de abeja. La cera de candelilla tiene dos defectos principales, que hacen hasta cierto punto díficil su empleo y son: La dificultad de blanqueo y la cantidad de resinas que contiene; sin embargo, mezclada con otras ceras se puede elevar su punto de fusión, utilizándose con ventaja en la elaboración de velas, se usa con bastante amplitud en la fabricación de betunes para calzado, interviene en las sustancias que se emplean en la elaboración de las grasas y betunes para las pieles.

Se aprovecha la cera de candelilla en la fabricación de barnices de color, pues una vez evaporados los disolventes, queda una superficie brillante constituida por una ligera capa de cera que sirve de protección también se mezcla con caucho para la fabricación de artefactos electricos, tales como aisladores. El Gobierno de los Estados Unidos de Norteamerica utilizó grandes cantidades de cera de candelilla para impremeabilizar las tiendas de campaña que necesitó el ejercito durante la segunda guerra mundial; se mezcla con el chicle y otras gomas de procedencia oriental, para obtener un producto de mascar; se usa también en la fabricación de cosmeticos, cerillos, explosivos, discos de fonógrafo, bujias, papel stencil, y papel carbón entre otros.

INVESTIGACION.- El desarrollo del presente trabajo, se llevó a cabo debido a la escasez de información sobre la existencia de planta de candelilla en poblaciones naturales; otra de las razones de la elaboración de dicha investigación es la sobre explotación a que ha sido sometida la especie bajo estudio en últimas fechas, ello con el fin de cubrir las necesidades de cera dentro del país como de los requiriemientos de exportación; lo cual ha traido como consecuencia que el recurso candelilla se encuentre en vías de extinción, debido a que año con año se elevan las cuotas de producción; se otorgan incentivos para los campesinos que obtengan incrementos mayores del 70% en la producción mensual de cerote, y también a que existe el contrabando de cera de candelilla hacía el extranjero.

Anteriormente los campesinos candelilleros se desplazaban a colectar la hierba, a una distancia promedio de 5 a 8 kilometros de los centros de población; en la actualidad es necesario que se trasladen 40 o más kilometros para completar su carga, teniendo en ocaciones que pargar renta de vehículo por el traslado de la planta, debido a la distancias considerables que tendrían que caminar los animales de carga, también se han dado algunos casos que han colocado pailas en las cercanias a los lugares donde actualmente extraen la planta; otros más ya han terminado con el recurso que existia dentro de sus terrenos teniendo ahora la obligación pagar la cantidad de $5.00 por kilogramo de cerote obtenido, por concepto de renta a propietarios vecinos que les arriendan sus predios para que sean sometidos a explotación.

Para la realización de este estudio se hizo un recorrido por los ejidos candelilleros del Norte de Coahuila, efectuando muestreos tecnicos y socioeconomicos en las areas bajo explotación, todo lo cual sirvió para el desarrollo del presente estudio como un muestreo preliminar.

La superficie donde se efectuo el trabajo, se localiza dentro de los terrenos del Campo Experimental Forestal "La Sauceda", Coah, siendo un Area expuesta a explotación en donde se delimitó la zona poblada por candelilla, siendo esta de 180

hectáreas, excluyendo caminos y lugares escarpados con el propósito de reducir el error.

El número de unidades de muestreo en la —población fue de 18,000, siendo estas de 10 X 10 M ($100M^2$), obteniendo un tamaño de muestra de 43 sitios, escogiéndolos al azar es una tabla de numeros aleatorios.

El tipo de muestreo fue el "Muestreo Simple aleatorio", por ser el más adecuado de acuerdo al trabajo a desarrollar.

Las variables de interés fueron:

- Número de plantas aprovechables
- Altura de plantas
- Cobertura
- Número de hijuelos por planta
- Número de plantas no aprovechables

De acuerdo al muestreo efectuado, se obtuvieron los siguientes promedios por hectárea:

1 200 Plantas aprovechables
2 212 Plantas aprovechables
26.85 cm de altura
368.02 cm^2 de cobertura
11.75 Hijuelos por planta (regeneración natural).

Si aproximadamente una carga de hierba pesa 100 kilogramos, entonces una carga estará compuesta de un promedio 200 plantas, las que produciran tres kilogramos de cerote y considerando que se - determinó un promedio de 1,200 plantas por hectárea; entonces se tendrá una producción aproximada de 18 kilogramos de cerote por hectárea; esta producción no es, anual sino que puede variar de 2 a 5 años dependiendo de las condiciones termo—pluvio metricas que prevalezcan.

Por todo lo anterior, se puede concluir que en el País existen en este momento, una producción potencial de 252 millones de toneladas de cera disponible. Por lo que se recomienda efectuar plantaciones de candelilla, en las regiones que anteriormente existia el recurso, de acuerdo a las tecnicas desarrolladas en el Campo Experimental Forestal "La Sauceda", Coahuila perteneciente al INIF; Así mismo se recomienda establecer cuotas rigidas de producción de acuerdo con la existencia de planta en cada ejido y que los terrenos que están sometidos a constante explotación, se dejen descansar por espacio de 2 a 3 años, para la regeneración de la planta, uno de los recursos que a hecho sobrevivir a los campesinos del Desierto Chihuahuense.

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A Precision Based Strategy for Allocating Sampling Effort in Nation-wide Surveys of Livestock and Wildlife[1]

Donald G. Peden[2]

Abstract.--A stratified systematic sample of livestock and wildlife was used to assess factors affecting precision of population estimates in nation-wide surveys. Sample sizes, areas of the strata, animal density, and group size were important. Non-linear programming was used to allocate sampling effort among strata. The costs of achieving different objectives were compared.

INTRODUCTION

The Kenya Rangeland Ecological Monitoring Unit (KREMU) was established in 1976 to develop the basis for reliable and continuous flow of information on livestock, wildlife and cultivation in the rangelands of Kenya. Development of the methodology for conducting reliable nation-wide censuses of animal populations has been a priority. This report describes the way in which KREMU evaluates the precision of its estimates of population sizes and in which KREMU is able to determine the sampling effort or flying time required to achieve a desired level of precision.

METHODS

Stratified Systematic Sampling of Kenya's Rangelands

The rangelands of Kenya, which cover approximately 480,000 square km, were stratified into 44 strata or eco-units. These eco-units (Fig. 1) were based on Pratt and Gwynne's (1977) eco-climatic zones, on available topographic, geologic and soil maps, on LANDSAT images and on interpolations based on reconnaissance flights. The aerial survey method (Norton-Griffiths, 1978) used east-west transects spaced at intervals along the Universal Transverse Mercator (UTM) grid lines and an above-ground altitude of 300 ft (91 m). Altitude was measured with radar altimeters and navigation was accomplished with a global navigation system (GLS 200). Ground speed was approximately 150 km/hr although higher speeds were necessary at times when tail winds were excessive. Two observers in the rear seats of Cesna 185 aircraft each counted animals seen in a strip measuring 5 km by 112 m wide on the ground on their respective sides of the aircraft. The animal counts from the two observers were summed and recorded on the basis of the UTM grid to the nearest (5 x 5) km^2 unit. These units are the basis by which KREMU stores census data in its data bank.

Calculation of Population Estimates and Standard Errors

The formulae used to estimate population sizes and their standard errors are those given by Jolly (1969), method 1,:

$$PE = N\bar{y} \quad (1)$$

$$SE = \sqrt{\frac{N\,(N-n)\,S^2y}{n}} \quad (2)$$

where PE is the population estimate, SE is the standard error of the estimate, y is the sample mean, S^2y is the sample variance, n is the sample size, and N is the number of observations required to give complete coverage of the study area. Strictly speaking, these formulae apply to random not systematic sampling. The possible occurrence of autocorrelation among the observations in a systematic sample will likely result in an upward bias of the sample variance when equation 2 is applied. However, Norton-Griffiths (1978) has successfully applied these equations to systematic samples. KREMU has made one additional departure from tradition in analyzing data. KREMU has retained the 5 km segments of each transect as the observation. This departure from tradition will likely result in greater autocorrelation (Smith 1980) among the observations but tests on KREMU's data indicated that this is not an important factor.

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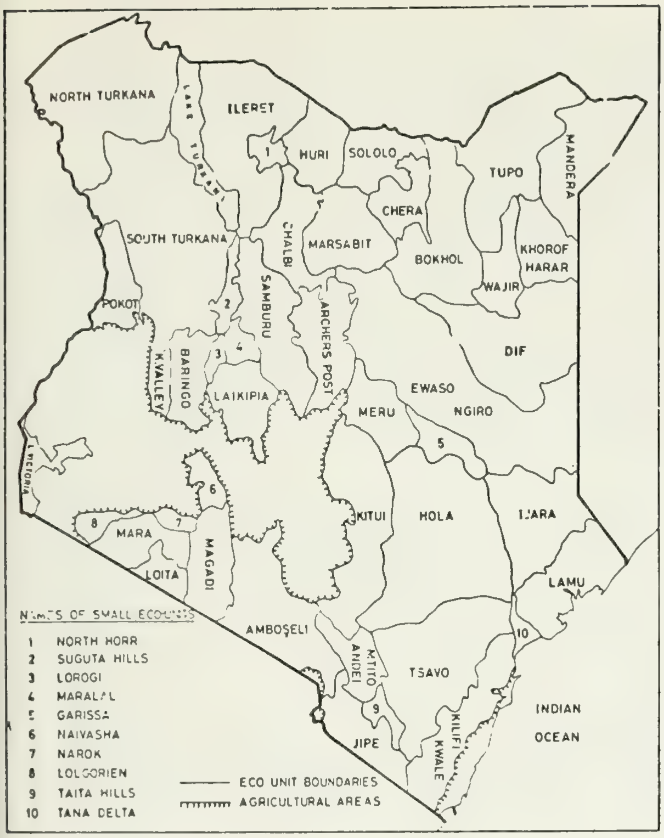

Figure 1.--The eco-units or strata used in a nation-wide systematic aerial survey of Kenya.

Evaluating Precision

In evaluating relative precision KREMU uses the standard-error-percent, SE%:

$$\mathrm{SE\%} = \frac{(\mathrm{SE})\ (100\%)}{(\mathrm{PE})} \tag{3}$$

By defining the coefficient of variation of the data, CV, as:

$$\mathrm{CV} = \frac{(Sy)\ (100\%)}{\bar{y}} \tag{4}$$

where Sy is the standard deviation of the sample data, CV becomes a measure of the relative variability in the distribution of animals on the ground. By substituting equations 1, 2 and 4 into equation 3, we get:

$$\mathrm{SE\%} = \frac{\sqrt{\dfrac{N\ (N-n)\ S^2y(100\%)}{n}}}{(N\bar{y})}$$

$$= \mathrm{CV}\sqrt{\frac{1}{n} - \frac{1}{N}} \tag{5}$$

From equation 5, it is apparent that the relative precision, SE%, depends on only three factors, namely CV, n and N. By solving for n in equation 5 and by specifying the level of relative precision which we desire in a census, we can select an appropriate sample size:

$$n = \frac{(\mathrm{CV})^2}{(\mathrm{SE\%})^2 + \dfrac{(\mathrm{CV})^2}{N}} \tag{6}$$

Once n has been determined, flying time, F, can be calculated as follows:

$$F = \frac{(n)\ (L)}{S} \tag{7}$$

Where L is the distance flown in each observation (5 km in KREMU's surveys) and where S is the speed of the aircraft (150 km/hr).

The Effects of n, N, and CV on Relative Precision

Population estimates, standard errors, SE%, CVs, and animal densities were calculated for livestock (cattle, sheep and goats) as a group in each eco-unit or stratum of the 1977 nation-wide census. The relative precision obtained for each is discussed in light of varying sample sizes and varying areas for the strata. The sample sizes and flight times required to give a SE% of 10% were estimated for each eco-unit.

An analysis of covariance was used to test for differences in the coefficient of variation of the data for sixteen different animal species in 44 eco-units. Covariates were Log average group size in the non-zero observations for each eco-unit and Log average density for each eco-unit. Group size approximates herd size but on occasions more than one herd was included in a group and on occasions only part of a herd was included within an observation. After correcting for differences in the density and group size, a test was made for differences in the coefficients of variation among the sixteen animal species.

Allocation of Sampling Effort Among Eco-Units

Equation six can be used to estimate the sample size required to obtain any desired level of relative precision in one eco-unit or stratum once CV and N are known. Equation six does not indicate the most efficient allocation of sampling effort when population estimates are required over more than one stratum.

The SE of population estimates for T eco-units or strata, SE', is:

$$SE' = \sqrt{(SE_1)^2+(SE_2)^2+\ldots+(SE_T)^2} \quad (8)$$

The relative precision for T eco-units or strata, SE%', is:

$$SE\%' = \frac{(SE')\ (100\%)}{(PE_1)+(PE_2)+\ldots+(PE_T)} \quad (9)$$

Allocating sampling effort in the most efficient way was formulated as a non-linear programming problem as follows:

$$\text{MIN } G = n_1 + n_2 + \ldots + n_T \quad (10)$$

$$\text{Such that} \quad SE\%' \leq 5\% \quad (11)$$

Equations 10 and 11 state that the problem of allocating sampling effort is to find the minimum sum of sample sizes for all strata such that relative precision for the population estimate of the entire area, which is composed of all strata, is not greater than five percent. The solution to this problem was found for KREMU's nation-wide survey of livestock for 1977. This problem was solved using an iterative method programmed in BASIC. In each iteration the partial derivatives describing the rate of change of SE%' with respect to the sample sizes, n, for i = 1 to 44 strata, were evaluated:

$$\frac{d(SE\%')}{dn_i} = - \frac{(CV_i)^2}{2n_1^2 \sqrt{(CV_1)^2(\frac{1}{n_1} - \frac{1}{N_1})+\ldots+(CV_{44})^2(\frac{1}{n_{44}} - \frac{1}{N_{44}})}} \quad (12)$$

To the sample size of the stratum which was characterized by the most negative partial derivative, one sample unit was added before starting the next iteration. Repeated iterations were completed until the inequality of equation 11 became true.

RESULTS

The results of the 1977 nation-wide livestock census are summarized for each eco-unit in Table 1. The eco-units ranged in size from 40725 km to 1050 km^2. Animal densities ranged from 81.3 to 1.5 animals per km^2. The population estimates and their standard errors varied greatly. North Turkana was the most populated with 1,345,602 animals estimated and Khorof Karar was the least populated with 11,465 individuals estimated. The relative precision, SE%, varied greatly ranging from 75.5% in Chera to 8.0% in Kitui. The coefficient of variation of the data, CV, also varied greatly from 918 in Tsavo to 131 in Baringo. Mean group size of livestock ranged from 222 in Lamu to 31 in Mtito Andei.

The sample sizes and flying time required to produce an SE% of 10% in each eco-unit are also given in Table 1. These estimates of sampling effort varied greatly ranging from 198.0 hrs in Tsavo to 5.6 hrs in Baringo. The largest estimates of sampling effort were associated with those strata where the CV was high as characterized by a comparison of the Lamu, the Wajir, and the Baringo eco-units which each covered 6675 km^2. A comparison of the Amboseli and Lolgorien eco-units which varied in size but in which the CVs sere similar demonstrated that in large eco-units the number of samples and the amount of flying time required were greater in small eco-units but the sampling fraction in large eco-units was less than that in small ones.

The analysis of covariance (Table 2) demonstrated that after correcting for density and group size, there were no significant ($p = 0.16$) differences in the CV of the sixteen species of animals considered. From this analysis, the following regression was derived:

$$CV = 959\text{Log}(G) - 825\text{Log}(D) - 522 \quad (13)$$

where G is the average group size and D is the average density. These two independent variables in equation 13 accounted for 86% ($R^2 = 0.863$) of the variability of CV observed in 16 species over 44 eco-units.

The optimal distribution of sampling effort for a nation-wide survey of livestock is given in Table 1. This solution to the problem, which is defined in equations 10 and 11, assumes that the acceptable level of relative precision, SE%', is 5%. A comparison of this solution with the distribution of sampling effort in the 1977 survey indicates that the sampling effort actually used was three times more than that necessary to achieve this objective. A comparison of this solution with the sampling effort needed to obtain SE% of 10% for each eco-unit demonstrates enormous differences. To achieve SE% of 10% for each eco-unit would require an estimated 1742 hrs of flying time but to achieve SE%' of 5% for the whole country would require only about 101 hrs of flying time. An examination of the Tsavo eco-unit demonstrates that 198 hours of flying are needed if relative precision of 10% is required for this stratum but only 2.3 hours of flying are needed if the objective is to achieve relative precision of 5% on the estimate of livestock for the entire country.

DISCUSSION

The coefficient of variation of the data, CV, is the prime factor affecting relative precision of the population estimates (SE%). For any desired species of animal and for any desired eco-unit or stratum equation 13 can be used to estimate CV if the density and group size are approximately known. This estimate of CV can be used with equation 6 to estimate the sample size, n, required to achieve a desired level of relative precision. This estimate of n can be converted to an estimate

Table 1.--Comparison of sample sizes(n) and flying times (f) for the 1977 nation-wide survey of livestock and for the objectives of obtaining SE% of 10% in every strata and of obtaining SE% of 5% for the estimate of all strata combined. The population estimates in thousands (PE), the relative precision (SE%), the coefficients of variation (CV), the mean densities in NO./Km^2 (D) and mean group sizes (G) for 1977 are also given.

Eco-unit	Area (Km^2)	PE	SE%	CV	D	G	1977 Census		SE% of 10%		SE% of 5% (all strata)	
							n	F	n	F	n	F
Ewaso Ngiro	40725	493	16.7	474	12.1	94	791	26.4	2114	70.5	230	7.7
South Turkana	36025	1158	9.6	260	32.1	95	716	23.9	662	22.1	290	9.7
Hola	32100	288	17.4	451	9.0	70	652	21.7	1888	62.9	130	4.3
North Turkana	29825	1346	10.0	243	45.1	124	576	19.2	578	19.3	310	10.3
Tsavo	22450	73	42.9	919	3.2	144	449	15.0	5941	198.0	70	2.3
Dif	21400	197	20.6	404	9.2	67	377	12.6	1505	50.2	80	2.7
Ileret	20725	131	36.1	722	6.3	176	392	13.1	4064	135.5	90	3.0
Tupo	20275	206	23.0	453	10.1	96	390	13.0	1882	62.7	90	3.0
Kitui	18425	694	8.0	154	37.7	52	360	12.0	235	7.8	110	3.7
Amboseli	16575	1024	10.1	186	61.8	132	331	11.0	339	11.3	180	6.0
Bokhol	16425	60	26.5	489	3.6	55	332	11.1	2057	68.6	30	1.0
Ijara	13950	355	22.8	372	25.4	200	260	8.7	1244	41.5	130	4.3
Samburu	13625	453	14.7	239	34.0	99	271	9.0	544	18.1	110	3.7
Mandara	13275	142	23.9	358	10.7	60	221	7.4	1157	38.6	50	1.7
Kilifi/Kwale	11975	417	12.5	195	34.8	77	237	7.9	366	12.2	80	2.7
Archer's Post	10625	180	24.5	360	16.9	127	211	7.0	1294	43.1	70	2.3
Marsabit	10525	120	30.8	437	11.4	132	197	6.6	1587	52.9	50	1.7
Chalbi	8850	101	36.6	497	11.4	120	180	6.0	1881	62.7	50	1.7
Magadi	8750	432	15.6	210	49.4	147	176	5.9	417	13.9	90	3.0
Jipe	8275	35	32.4	420	4.2	49	164	5.5	1425	47.5	20	0.7
Laikipia	8275	380	13.6	172	45.9	90	158	5.3	286	9.5	70	2.3
Meru	8075	165	26.2	361	20.5	96	185	6.2	1104	36.8	60	2.0
Khorof Harar	7575	11	65.3	745	1.5	38	128	4.3	3051	101.7	10	0.3
Buri	7525	52	41.5	512	7.0	79	149	5.0	1884	62.8	30	1.0
Sololo	7175	34	51.6	594	4.8	68	130	4.3	2277	75.9	20	0.7
Mara	6850	311	18.3	217	45.4	129	137	4.6	438	14.6	70	2.3
Lamu	6675	89	52.5	785	13.4	222	216	7.2	3032	101.7	70	2.3
Wajir	6675	121	27.6	312	18.2	83	125	4.2	835	27.8	40	1.3
Baringo	6675	338	11.2	131	50.6	79	134	4.5	168	5.6	50	1.7
Chera	6475	15	75.5	810	2.3	64	113	3.8	3074	102.5	20	0.7
Pokot	5850	266	14.7	157	45.4	79	112	3.7	235	7.8	40	1.3
Mtito Andei	4900	41	23.4	234	8.4	31	99	3.3	492	16.4	10	0.3
Garissa	3975	157	19.5	228	39.4	126	132	4.4	454	15.1	40	1.3
Loita	3000	161	22.4	175	53.6	103	60	2.0	275	9.2	30	1.0
Suguta Hills	2725	31	34.0	243	11.4	56	50	1.7	475	15.8	10	0.3
Naivasha	2500	154	25.2	178	61.7	100	49	1.6	278	9.3	30	1.0
Kerio Valley	2425	144	22.5	158	59.5	73	48	1.6	223	7.4	30	1.0
Maralal	2100	171	31.0	206	81.3	120	43	1.4	345	11.5	40	1.3
Lolgorien	2025	60	36.5	187	29.8	86	26	0.9	294	9.8	20	0.7
North Horr	1875	41	65.4	397	21.7	130	36	1.2	811	27.0	20	0.7
Taita Hills	1725	40	27.2	150	23.4	47	30	1.0	197	6.6	10	0.3
Narok	1275	81	30.7	152	63.8	117	24	0.8	192	6.4	20	0.7
Tana Delta	1225	79	51.7	249	64.6	211	23	0.8	397	13.2	20	0.7
Lorogi	1050	18	40.4	188	17.6	46	21	0.7	257	8.6	10	0.3
Total Rangelands	482425	10865	3.08	315	22.7	96	9511	317.0	52254	1741.8	3030	101.0

of required flying time by solving equation 7. Such an estimate of flying time does not include ferry time or time spent flying between transects.

With respect to surveys of only one stratum, required sampling effort and flying time will be greatest in cases where the animals occur in large groups at low densities and where the area is large. Smaller areas require less flying time.

In extending the survey to more than one stratum, equations 10 and 11 can be used to efficiently allocate sampling effort among various strata. In this case, the required sample size is low in strata with low densities. Thus there is a conflict if a stratum with low density is important in itself and if this stratum is not merely a tool to be used in allocating sampling effort to this stratum to give acceptable precision on the estimate of the population does not contribute much to improving the precision of the population estimate of the entire area. For example (Table 1) if the Khorof Harar eco-unit is important to livestock management and if relative precision of 10% is required for the population estimate, then 102 hrs of flying time are required. However, if this stratum is only a tool to be used in efficiently allocating sampling effort to obtain an estimate of a nation-wide population, then only 20 min of flying time are needed. In fact, obtaining SE%' of 5% for all of Kenya's rangelands which cover 482,000 Km^2 requires approximately the same sampling effort as obtaining a SE% of 10% for the Khorof Harar stratum which covers only 7575 Km^2.

The development of an efficient multispecies and multi-purpose animal census program requires clear objectives. Acceptable relative precision for estimates of specific species and specific areas must be specified. From this, area-specific sampling efforts can be calculated using equations 6 or 10 and 11. Then allocation of sampling effort for a nation-wide census can be accomplished by applying equations 10 and 11 and by adding new constraints to the non-linear programming problem. For example, if it is determined that 100 sample units (n = 100) are needed in the 5th stratum, which is Tsavo, in order to estimate the elephants in this specific area, then a new constraint is added to the problem as follows:

$$\text{Such that} \quad n_5 \geq 100 \qquad (14)$$

By systematically specifying additional constraints, the most efficient nation-wide sampling schedule which can be determined from equations 10 and 11 alone, can be altered to accommodate the species-specific and area-specific objectives.

Caution is required in using these results. The method of allocating sampling effort assumed a prior knowledge of the coefficient of variation which implies a prior knowledge of the density and group size of the animals. If this prior knowledge is available then there is little need of repeating a census. Furthermore, the estimates of CV have associated error terms and the true CV will likely vary with time for any given kind of animal. Therefore, these results should be used as a guide in which the user also takes into account likely changes in densities and group changes on his ability to obtain precise estimates of population sizes.

Table 2.--Analysis of covariance of the effects of group size, animal density and other interspecific differences on the coefficient of variation.

Source of Variation	DF	MS	F	Sig.
Log group size	1	36859744	1145	.001
Log density	1	78111152	2427	.001
Species	15	43676	1.36	.165
Residual	411	32182		

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RESUMEN

En la evaluación de factores que afectan la precisión en el estimado de la población de ganado y de vida silvestre en encuestas nacionales, se utilizó una muestra sistemática estratificada de esa población. Los tamaños de la muestra, áreas de la estrata, la densidad animal y el tamaño del grupo fueron factores de mucha importancia. Se utilizó una programación no-linear en la asignación de la tarea de muestreo en las diferentes estratas. Se compararon los costos incurridos para lograr los diferentes objetivos.

Sampling and Description of Vegetation for Large Scale Mapping at Organ Pipe Cactus National Monument[1]

Peter L. Warren[2]

Abstract.--Desert vegetation of Organ Pipe Cactus National Monument, Arizona was mapped at 1:24,000 scale using natural color aerial photography in conjunction with detailed ground survey methods. Field documentation included estimating prominence and cover of vegetation and recording terrain characteristics. Vegetation description emphasized floristic composition, physiognomy and the relationship of both to terrain features. The detailed descriptive legend not only identifies vegetation associations, but can also be used to extract more specific resource information. For example, distribution and abundance of columnar cacti were isolated for management purposes and distribution of jojoba was mapped to identify critical white-tail deer habitat.

INTRODUCTION

Vegetation sampling and description ranges in intensity from continental scale, generalized work such as that of Küchler (1964) to very detailed, quantitative studies of local variation, for example, that of Whittaker and Niering (1965). The design of a vegetation survey must take into consideration the kind of information desired from the project and the resources, time and manpower available for the project execution. Mapping vegetation at a large scale allows discrimination between closely related vegetation associations and requires detailed vegetation descriptions to characterize the various associations. This paper describes the methodology used to map desert vegetation at a scale of 1:24,000 in southern Arizona.

From September, 1977 until August, 1979 a vegetation survey and mapping project of Organ Pipe Cactus National Monument was performed by the Applied Remote Sensing Program, Office of Arid Lands Studies at the University of Arizona in cooperation with the U.S. National Park Service. The objectives of the project were to identify, describe and map the natural vegetation associations of the monument in a manner that would provide baseline information useful for management decisions and future scientific research in the monument. The sampling and descriptive methodology employed reflects a compromise between obtaining information of sufficient detail to establish a useful and reliable data base and completing the survey of a large area (517 square miles) in a reasonable length of time.

The monument is located near the geographic center of the Sonoran Desert in southern Arizona immediately adjacent to the international boundary between Mexico and the United States. The monument encompasses an area of 517 square miles ranging in elevation from approximately 1,000 feet on the western boundary to 4808 feet at the crest of the Ajo Mountains which form the eastern boundary. The physiography of the area is typical of the Basin and Range province of southwestern Arizona and northwestern Sonora (Dunbier, 1968). Extensive alluvial plains averaging approximately 1600 feet in elevation are punctuated by scattered, low mountain ranges which commonly rise to elevations

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approximately 1500 feet above the surrounding plains.

The monument lies in a region of floristic intergradation between three of the seven major subdivisions of the Sonoran Desert described by Shreve (1964). Two of these subdivisions, the Arizona Upland and Lower Colorado, are represented by plant associations typical for these subdivisions. The third, the Central Gulf Coast subdivision, is represented by relictual stands of characteristic species, but not complete species assemblages (Steenbergh and Warren, 1976). In addition to the desertscrub vegetation which dominates the monument landscape, the Ajo Mountains provide sufficient elevational relief to permit populations of non-desert species to persist. These include species characteristic of chaparral and woodland communities found adjacent to the Sonoran Desert and scattered within the desert region on the taller mountain ranges (Brown, 1978). This mixing of species from several phytogeographic groups produces the high floristic diversity found in the monument.

METHODOLOGY

Vegetation mapping was performed at two scales, 1:24,000 and 1:62,500, by interpretation of natural color aerial photographs of 1:24,000 scale and concurrent collection of ground-level vegetation data. Sampling intensity and the amount of information used in describing vegetation associations was directed at the larger, more detailed scale. While detailed information can be generalized to provide a suitable legend for a smaller scale map, the opposite is not possible.

Sampling Procedures

Vegetation sampling was accomplished using a subjective prominence ranking similar to that of Braun-Blanquet (1932) adapted for use in arid and semi-arid parts of southern Arizona by Johnson, et al. (1974), and visual estimates of total vegetative cover. Sampling procedures involved selecting a sample site, making a complete list of perennial plant species for the site and finally estimating prominence and cover for each species.

Sample Site Selection

Locations for vegetation samples were chosen on the basis of several criteria including homogeneity of vegetation, homogeneity of terrain and representation within mapping units. After preliminary mapping on aerial photographs, fieldwork was planned to establish sample sites within each type of unit (vegetation association) distinguished on the photo.

Within each unit delineated on the aerial photographs there may exist variation in physical parameters including elevation, slope aspect, soil texture and others. The distribution of plants reflects the variation in physical features, to a greater or lesser degree, such that no mapping units are strictly homogeneous. To permit comprehensive description of each vegetation association, sample sites were chosen to document the range of variation within each mapping unit. Sites were located at the highest and lowest elevations at which a type was found, as well as at intermediate elevations. Similarly, sites were located on all slope aspects and on all different soil types within a unit.

Each vegetation sample was selected to cover an area which was as homogeneous as possible and included approximately ½ to 1 hectare. Areas of differing topography or slope aspects would not be included in a single sample plot. For example, on a hillside adjacent to an alluvial plain, a single plot would not include both landforms, but one plot may be located on the plain and another on the hillside to document the difference in vegetation, if any, between the two. Similarly, adjacent north-facing and south-facing slopes were not included in one plot.

Topographic constraints often determined the size and shape of the sample plots, particularly in the case of small, but highly contrasting vegetation associations. For example, a fairly small north-facing hillside may have vegetation clearly different from that on surrounding flats, but the maximum size of the sample plot would be constrained by the extent of the hillside. Similarly, a plot in a riparian association would not extend onto adjacent uplands.

Vegetation Sampling

After the location and extent of study plots were established, the perennial plant species on the plots were listed and their prominence and cover estimated. Emphasis was placed on perennial species because, although some annual species may be very characteristic in some vegetation associations, they are not reliable indicators at all times of the year, and may appear in widely varying abundances from year to year.

Each species is ranked in prominence on a scale of 1 to 5 which follows the definitions used by Johnson, et. al. (1974). A "5" is given to only one species in a stand and indicates a single species which is clearly more visually prominent than any other species and is abundant when looking in all directions from the center of the sample plot. If no single species is clearly most prominent, the "5" rank may be omitted. Species which are abundant when looking in all directions from the center of the sample plot, and clearly stand out

on the landscape receive a "4". If no single species is clearly most prominent, two or more species sharing the most prominent position receive "4". Species which are scattered but occur uniformly throughout the stand and can be easily seen from the center of the plot receive a "3". Species which are widely scattered and difficult to see, perhaps requiring some walking to locate in the plot, receive a "2". Finally, species which are rare on the plot and require several minutes of intent searching to locate receive a"1".

Vegetative cover was estimated for each species and for all species combined on each plot. Cover estimates were based upon cover measurements made on permanent study plots in several parts of the monument by Steenbergh and Warren (1976).

In addition to recording floristic characteristics at each plot, several physical environmental features were recorded. These included landform, elevation, slope angle, slope aspect, soil texture, and soil parent material. Terrain features such as these were important both for aid in interpretation of aerial photographs and in providing a detailed description of the distribution of each vegetation association.

Vegetation Description

Each vegetation association was described on the basis of three main features: floristics, physiognomy and distribution. The level of detail used in the description of each of these features is a logical extension of the descriptive legends of much smaller scale maps such as that of Küchler (1977). Although the same basic kinds of information can be used to describe mapping units at all mapping scales, at larger scales increasingly detailed descriptions are necessary to adequately characterize and distinguish between similar mapping units (Table 1).

A floristic summary is the central part of the vegetation association description. After field sampling is completed, the data from all plots is compared and classified into vegetation associations to be used as mapping units on the basis of floristic similarity. The floristic data from all plots in each association is summarized by calculating a mean (average) prominence value, and a frequency of occurrence for each species. The mean prominence values reflect only those plots where a given species occurred. If a species was absent from a plot a zero value was not included in the calculation. If a species received a mean prominence value greater than 2.0 and a frequency greater than 0.5 in an association it was considered to be a "characteristic" species of that association. Species of lesser prominence and frequency were considered to be associated species.

Table 1.--Description of a desertscrub vegetation association at Organ Pipe Cactus National Monument. The name of the association is derived from the first three characteristic species.

Name: *Cercidium microphyllum - Ambrosia deltoidea - Larrea tridentata* association.

Distribution:

This type occurs on nearly level to rolling terrain from 1,500 to 2,000 feet elevation at the base of the Puerto Blanco, Bates and Growler Mountains. The type is found on very coarse soil shallowly underlain by bedrock which is exposed in the bottom of incised drainageways. The terrain is often moderately to highly dissected. *Neolloydia erectocentra* is generally restricted to this type in the vicinity of the Puerto Blanco Mountains.

Floristics:

Characteristic Species	Prominence Range	Prominence Mean	Frequency (34)
Cercidium microphyllum	3-4	3.5	1.0
Ambrosia deltoidea	2-4	3.6	1.0
Larrea tridentata	1-4	3.3	1.0
Carnegiea gigantea	1-4	2.3	1.0
Fouquieria splendens	1-4	2.8	0.8
Encelia farinosa	1-4	2.6	0.7
Lemaireocereus thurberi	1-?	1.9	0.8
Opuntia fulgida	1-4	2.6	0.6
Opuntia acanthocarpa	1-3	2.2	0.7
Olneya tesota	1-[illegible]	2.0	0.6
Associated Species			
Opuntia bigelovii	1-3	2.5	0.5
Krameria grayi	1-3	1.9	0.5
Jatrophia cuneata	1-4	2.4	0.3
Lycium spp.	1-3	2.0	0.3
Echinocereus engelmannii	1-3	2.0	0.3
Ferocactus covillei	1-2	1.2	0.3
Ambrosia dumosa	2-3	2.4	0.2
Sapium biloculare	1-2	1.4	0.2
Mammillaria microcarpa	1-2	1.6	0.2
Ephedra aspera	1-3	2.3	0.2
Opuntia leptocaulis	1-2	2.6	0.1
Celtis pallida	2	2.0	0.1
Acacia constricta	1-2	1.1	0.2
Jatropha cardiophylla	1	1.0	0.1

Physiognomy:

A diverse mixture of deciduous trees, evergreen and deciduous shrubs, and cacti with total cover of 25 to 35 percent. The height of shrubs ranges from 2 to 4 feet, trees from 10 to 15 feet and cacti from 6 inches to 30 feet. This type is transitional between the Paloverde - Brittlebush types of the hillslopes and tends to be more diverse than either of those as a result of mixing of species from both types

The minimum number of sample plots necessary to adequately describe an association was approximately ten to fifteen. Variation in species diversity between associations can have a major effect upon the number of samples required. A very simple association, for example, a creosotebush flat, may contain only three to five perennial species and be very homogeneous over large areas. Simple associations such as this require less intensive sampling to obtain suitable representation of all species than an association such as that described in Table 1. The actual number of samples collected in each association depends largely upon the extent of each association. Some vegetation types cover large areas and necessitate many more samples to document their distribution and satisfactorily describe them. On the other extreme, a few associations occupied very restricted habitats and the limited distribution of these types made it impossible to collect more than a few samples.

The distribution of each association is described on the basis of both regional and local patterns. Local distribution patterns include information on terrain features such as slope angle and aspect, soil texture, or the rock type on which an association is found. Regional distribution patterns include information on the geographical and elevational extent of each association. Both types of information are important in characterizing an association. For example, it is possible for two associations to have very similar geographic distribution patterns, but occur locally segregated as a result of different substrate requirements.

Physiognomy of each association is characterized on the basis of several features. The range of vegetative cover for each association is summarized from the cover estimates on all samples. The height of the important life-form categories (i.e., tree, shrub, cacti) in each association is estimated and the phenological character, either evergreen or deciduous, is recorded.

DISCUSSION

Several aspects of the sampling and descriptive methodology used at Organ Pipe were particularly advantageous for sampling and mapping large areas at a large scale. The descriptive format proved to be of particular value for comparing one vegetation association with another and for comparing individual samples with previously described associations for classification purposes. Use of a detailed association description permits flexibility of application and permits extraction of resource information whose importance was not anticipated at the time of the original survey.

The principal advantages of the sampling methodology were rapidity of sampling and uniformity of application of the method by several field workers. A documentation site could be sampled in approximately 15 to 20 minutes by an experienced worker. The 10 to 20 plots sampled per day by this method compares favorably to a rate of one plot per day for the 0.1 hectare study plots described by Warren (1979). Experienced botanists could produce similar results after a relatively brief training period, permitting rapid, comparable samples over a large area by a number of workers.

A comprehensive, detailed descriptive format allows great flexibility in applying the results of a vegetation survey to management and research problems. Vegetation information is often used at two levels, at the level of complete associations and at that of individual species. The descriptive results at Organ Pipe provide access to both of these types of information. This results in part from the comprehensive approach to both sampling and description. Surveys initiated to answer specific questions which focus on restricted species or vegetation characteristics may sacrifice information of unknown future value. The format described here seems to reflect a practical balance between a useful level of detail and complete treatment of important vegetation features.

Description of vegetation at any level of detail stands independent of classification, but versatility of classification is a major consideration in describing vegetation. Comparison of vegetation associations from one study with those from another may require a descriptive and/or classification format which is compatible with several classification systems. The descriptive format described here permits flexibility of classification at different hierarchical levels and on the basis of different vegetation characteristics. The results of this project were classified using the system of Brown, Lowe and Pase (1979) which emphasises floristic composition (Table 2). However, sufficient information is included in the association descriptions to permit classification of the associations on the basis of physiognomic features. This information allows comparison with results of other studies which use a physiognomic system as the UNESCO (1973) legend.

Frequently the botanical information needed for research or management purposes is not the distribution of a complete vegetation association, but that of only one or a few species. For some purposes floristic data is not needed at all and physiognomic information is necessary. Descriptive information was presented in this study in such a way that the distribution and relative abundance of any single species can be extracted and mapped individually. To a lesser extent vegetation physiognomy features such as height or cover can also be extracted and used independently

One primary reason for establishment of the monument was preservation of columnar cacti, whose life-form is unusual in the United States. Because of their importance to management planning the distribution and relative abundance of the three species of columnar cacti, Saguaro, Organ Pipe

Table 2.--Vegetation association of Organ Pipe Cactus National Monument classified by the system of Brown, Lowe and Pase (1979).

120 Forest and Woodland Formations
122 Cold temperate forest and woodland
122.4 Great Basin Conifer Woodland
122.41 Pinyon-juniper series
122.415 *Juniperus monosperma* association
*122.4151 *J. monosperma - Vauquelinia californica - Simmondsia chinensis* association

123 Warm temperate forest and woodland
123.3 Madrean Evergreen forest and woodland
123.31 Encinal (Oak) Series
*123.319 *Quercus ajoensis - Vauquelinia california - Acacia greggii* association

124 Tropical-subtropical forests and woodlands
124.7 Sonoran riparian woodland
124.71 Mesquite series
*124.411 *Prosopis glandulosa - Cercidium floridum - Ambrosia ambrosioides* association

130 Scrubland Formations
133 Warm temperature scrublands
133.3 Interior chaparral
133.36 Mixed evergreen sclerophyll series
*133.361 *Ribes quercetorum - Ptelea trifoliata - Rhamnus crocea* association

150 Desertland formations
154 Tropical-subtropical desertlands
154.1 Sonoran desertlands
154.11 Creosotebush - Bursage (Lower Colorado) series
154.111 *Larrea tridentata* associations
*154.1111 *Larrea tridentata - Ambrosia dumosa - Ambrosia deltoidea* association
*154.1112 *Larrea tridentata - Ambrosia dumosa - Opuntia fulgida* association
*154.1113 *Larrea tridentata - Ambrosia deltoidea - Fouquieria splendens* association
*154.1114 *Larrea tridentata - Ambrosia dumosa - Ferocactus wislizenii* association
*154.1115 *Larrea tridentata - Prosopis glandulosa - Lycium spp.* association
154.12 Paloverde - mixed cacti (Arizona Upland) series
154.121 *Cercidium microphyllum - Ambrosia deltoidea* association
*154.1211 *Cercidium microphyllum - Ambrosia deltoidea - Larrea tridentata* association
*154.1212 *Cercidium microphyllum - Ambrosia deltoidea - Carnegiea gigantea* association
*154.1213 *Cercidium microphyllum - Ambrosia deltoidea - Simmondsia chinensis* association
*154.1214 *Olneya tesota - Ambrosia deltoidea - Cercidium microphyllum* association
*154.1215 *Cercidium floridum - Prosopis glandulosa - Ambrosia ambrosioides* association
*154.1216 *Cercidium microphyllum - Ambrosia deltoidea - Olneya tesota* association
154.123 *Simmondsia chinensis* association
*154.1231 *Simmondsia chinensis - Encelia farinosa - Fouquieria splendens* association
*154.1232 *Simmondsia chinensis - Viguiera deltoidea - Eriogonum fasciculatum* association
*154.1233 *Simmondsia chinensis - Celtis pallida - Acacia greggii* association
*154.1234 *Simmondsia chinensis - Atriplex polycarpa - Eriogonum fasciculatum* association
154.126 *Encelia farinosa* association
*154.1261 *Cercidium microphyllum - Encelia farinosa - Jatropha cuneata* association
*154.1262 *Cercidium microphyllum - Encelia farinosa - Ambrosia deltoidea* association
*154.1263 *Cercidium microphyllum - Encelia farinosa - Ambrosia dumosa* association
154.127 *Cercidium microphyllum - Lemaireocereus thurberi* association
*154.1271 *Cercidium microphyllum - Encelia farinosa - Lemaireocereus thurberi* association
*154.1272 *Cercidium microphyllum - Ambrosia deltoidea - Lemaireocereus thurberi* association
154.17 Saltbush series
154.176 *Atriplex polycarpa* association
*154.1761 *Atriplex polycarpa - A. linearis - Larrea tridentata* association
*154.1762 *A. polycarpa - A. linearis - Suaeda torreyana* association
*154.1763 *A. polycarpa - A. linearis - Prosopis glandulosa* association

240 Marshland Formations
244 Tropical-subtropical marshland
244.7 Sonoran Interior Marshland
244.71 Cattail Series
244.711 *Typha domingensis* association
*244.7111 *Typha domingensis - Scirpus olneyi - Pluchea purpurascens* association
244.75 Saltgrass series
244.751 *Distichlis spicata* association
*244.751 *Distichlis spicata - Juncus cooperi - Sporobolus airoides* association

*Indicates mapping units used at Organ Pipe Cactus National Monument

Cactus and Senita, were mapped individually. Relative abundance was expressed as an importance value calculated from the original vegetation association descriptions. The importance value was calculated simply as frequency multiplied by average prominence for each species in each association. Distribution of the columnar cacti was then mapped on the basis of four importance value classes ranging from zero to a maximum possible of five.

The distribution patterns of the individual cacti were obscured on the maps of complete associations, particularly at the generalized scale. For mapping at 1:62,500 the individual associations were combined and generalized from the seventh classification level to the sixth (Table 2). As a result, in some cases associations in which a cactus species had two different importance values were mapped as a single unit and vice versa. Extracting and mapping individual species distributions separately produced a map which was much more easily interpreted than the general vegetation map.

Vegetation information can also be extracted from the association descriptions and used to indirectly evaluate other natural resources, particularly wildlife habitat. For example, if a correlation can be demonstrated between wildlife habitat requirements and vegetation characteristics, the vegetation map can be used to map wildlife distribution. At the monument, heteromyid rodents have been shown to have strict habitat segregation based upon total vegetative cover (Table 3). Two common heteromyid genera, Kangaroo rats *(Dipodomys)* and pocket mice *(Perograthus)*, are widely distributed throughout level parts of the monument, but the larger kangaroo rats are found where vegetation cover is low (<20%) and pocket mice are found in areas of higher cover (>20%). Using this information the distribution of these species can be mapped with fair accuracy from the vegatation maps.

A second example of indirect use of vegetation information is the distribution of whitetail deer which is rare in the monument (Henry and Sowles, 1979). Analysis of deer diet showed jojoba *(Simmondsia chinensis)* to be an important browse species and field observation further documented that the deer were generally restricted to sites with abundant jojoba. The distribution and relative abundance of jojoba was extracted from the vegetation descriptions as described above and used as an indicator of critical whitetail deer habitat. The map produced by this method is a much more useful tool for making specific management decisions than are the general vegetation maps.

Table 3.--Relationship between abundance of heteromyid rodents and vegetation cover in flatland desertscrub of Organ Pipe Cactus National Monument (from Warren, 1979).

Vegetation Cover	*Dipodomys* abundance*	*Perognathus* abundance*
3.43	20.0	4.0
7.47	12.4	1.7
7.55	13.0	2.0
9.75	4.9	4.9
9.96	15.4	1.5
10.51	6.0	6.0
10.87	18.2	1.0
12.29	16.4	0
15.20	14.6	5.4
16.27	11.2	5.6
16.64	9.0	6.4
20.10	11.3	0
21.86	6.8	24.2
22.46	2.3	16.2
25.51	0.5	21.7
27.64	0	16.7
27.74	0	13.9
28.24	0.8	23.7
32.72	2.1	16.4
41.36	0	36.8

*Number of captures/100 trap nights.

SUMMARY AND CONCLUSIONS

Desert vegetation was surveyed and mapped at a scale of 1:24,000 using detailed field documentation methods in conjunction with natural-color aerial photography. Visual estimation of prominence and cover of plant species was a rapid, reliable technique for sampling large areas.

Comprehensive, detailed descriptions of vegetation associations are advantageous for management and research applications for several reasons. The descriptive format allows flexibility of classification and therefore ease of comparison of the results of one study with that of another. Detailed vegetation description also makes possible analysis of individual plant species distribution. Wildlife distribution can be mapped if correlations between wildlife habitat requirements and vegetation features can be demonstrated.

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EJEMPLOS DE VEGETACION Y DESCRIPCION DE LA MISMA PARA DIBUJOS DE MAPAS A GRAN ESCALA EN EL ORGAN PIPE CACTUS NATIONAL MONUMENT

Peter L. Warren

La vegetación desértica del "Organ Pipe Cactus National Monument" se catalogó y se distribuyó en mapas en una escala de 1:24,000. El proyecto se llevó a cabo por medio del Programa de Interpretación Remota Aplicada (Applied Remote Sensing Program) de la Oficina de Estudios de Tierras Aridas de la Universidad de Arizona en cooperación con el Servicio de Parques Nacionales de los Estados Unidos. El lugar está localizado en el suroeste de Arizona en la frontera con México y abarca 517 millas cuadradas (133,903 hectarias). El área estudiada está en una región de intergraduación entre tres subdivisiones del Desierto Sonorense.

Los dibujos de mapas se hicieron interpretando las fotografías aéreas a color natural acompañadas por una colección hecha "in situ" de datos detallados de la vegetación. Los ejemplos de vegetación fueron seleccionados en base a la homogeneidad de vegetación y terreno dentro de las zonas representativas de cada asociación vegetativa. Las unidades de mapas fueron hechas de fotografías aéreas y se planeó el trabajo del desplazamiento al lugar viendo los diferentes tipos de unidades marcadas.

Cada asociación vegetativa (unidad de mapa) se describió usando un formato detallado y comprensivo con flora, distribución y fisiognomía. Cada especie en una asociación fue caracterizada por el termino medio de importancia y frequencia en los ejemplos de aquella asociación. Se encontraron aproximadamente 10 ó 15 ejemplos para describir adecuadamente una asociación.

Los métodos usados en este proyecto fueron ventajosos para dibujar mapas de áreas grandes a gran escala por varias razones. La recolección de ejemplos fue rápida y los ejemplos fueron lo suficientemente detallados como para proporcionar una información útil. Las descripciones comprensivas de las asociaciones vegetativas permitieron la flexibilidad de clasificación y así fue fácil la comparación con resultados de otros estudios. Se puede sacar de las descripciones y los mapas por separado la distribución e información de la abundancia relative de especies individuales. Por ejemplo, se dibujó el mapa de la distribución de los cacti columnares por razones de planificación y se usó la distribución de la jojoba como un indicador del habitat crítico del venado de cola blanca.

Inventario de la Erosión en la Patagonia, Argentina, Basado en Imágenes Landsat y Fotografía Aerea[1]

Clara P. Movia[2]

Abstract.--Wind and water erosion forms and related vegetation changes were studied at different scales using Landsat (visually), aerial photography, field observations and low altitude flight. Photointerpretation was based mainly on physiography and pattern-elements; the vegetation was used as indicator of deterioration and of erosion activity. Description, classification and distribution of erosion forms were obtained as well as area mesurements.

INTRODUCCION

La vasta región patagónica ubicada en el extremo Sur del continente Americano entre los 40° y 55°S, tiene una superficie aproximada de 700.000 km^2. Puede ser dividida en dos subregiones: la Cordillerana (20% de la superficie) con precipitaciones superiores a 600 mm (hasta 4000 mm en el límite con Chile), muy quebrada y cubierta por bosques y selvas templado-frías y la Extra-andina (80%) con clima semiárido frío, que abarca la precordillera y las extensas mesetas que descienden escalonadamente desde los 900 m s.n.m. hasta el Atlántico; su vegetación es un mosáico de estepa, semidesierto y matorral con reducidas superficies de vega. En esta subregión pastorean alrededor de 17.500.000 lanares con una producción de 60.000 ton de lana y 8.000 ton de carne, cuyo valor ascendía a 70.000.000 U$A en 1971 (Programa 39: INTA/FAO, 1972)(fig. 1).

En todo el semidesierto (hasta la isohieta de 350 mm), predomina la erosión eólica mientras que por encima de ese valor la incidencia de la erosión hídrica es mayor; entre los 350 y 600 mm, donde se desarrollan las estepas graminosas de mayor valor pasturil de la Patagonia, ambos tipos de procesos se superponen. En el rubro lana las pérdidas debidas a la erosión están ligadas directamente a la depreciación del vellón por acumulación de tierra; indirectamente, a través del deterioro de la vegetación, incide negativamente en la producción de lana/animal, en la calidad de la fibra y en el porcentaje de parición.

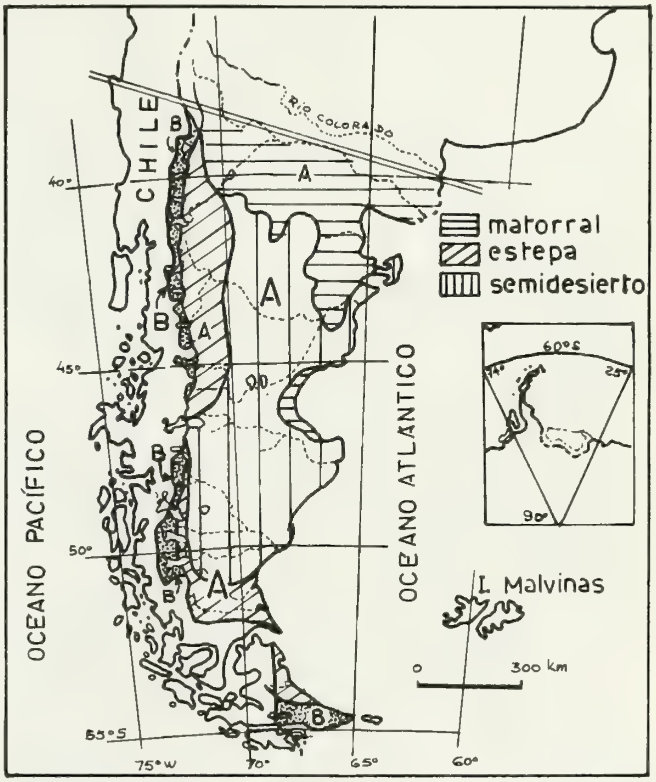

Figura 1.--La Patagonia Argentina. A)Zona Cordillerana (bosques y pastizales); B)Zona Extra-andina (semidesierto, estepa y matorral).

El inventario de la erosión y la evaluación de su gravedad comenzó en 1970 paralelamente con la implementación del Programa para el desarrollo ovino de la Patagonia (INTA/FAO 1967-72). Este programa incluyó el relevamiento de los recursos naturales de 3 áreas de 10.000 km^2 cada una, por el método del "Land System" (Christian 1958) basado en la fotointerpretación integrada.

[1]Comunicación presentada al Simposio sobre Arid Land Resource Inventories (La Paz, Mexico, Nov.30-Dic.6, 1980).

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A partir de 1975 se contó con imágenes LANDSAT las que fueron utilizadas en forma visual.

FACTORES QUE INFLUYEN EN LOS PROCESOS DE EROSION

A los fines de acotar el problema de la erosión patagónica es necesario puntualizar algunas características ambientales así como evaluar las modalidades del pastoreo y los inconvenientes emergentes de la insuficiencia de datos climáticos, la escasez de cartas topográficas a escalas adecuadas y la cobertura aerofotográfica incompleta; a ello deben sumarse la vastedad de la región, las dificultades de acceso de algunas zonas y las contingencias climáticas.

Clima.--En todo el semidesierto patagónico la dirección casi constante del viento (del Oeste), su alta intensidad y rafagosidad en la época de máxima evapotranspiración (octubre a marzo con velocidades que alcanzan los 200 km/h y promedios de 35km/h) determinan las peculiaridades de las formas eólicas y su actividad. A ello deben agregarse la amplitud térmica diaria, las intensas nevadas y el congelamiento superficial (y subsuperficial) del suelo que afectan su estabilidad y la de la vegetación. Desde el punto de vista de la erosión hídrica es importante el carácter de torrencialidad de las lluvias; las precipitaciones promedio varían entre los 150 y 270 mm anuales produciéndose en primavera y en otoño.

Vegetación.--Las estepas, matorrales y el semidesierto se caracterizan por su escasa cobertura y su altura reducidas (cuadro 1); tales características estructurales contribuyen a la alta susceptibilidad del sistema a la acción del viento.

Cuadro 1.--Altura y cobertura promedio de la vegetación en la Patagonia Extraandina. 1: desierto y semidesierto; 2: estepa arbustiva; 3: estepa graminosa; 4: matorral; 5: vega; 6: pastizales del ecotono bosque-estepa.

Tipos de Vegetac.	1	2	3	4	5	6
Cobertura en %	5-35	40-55	60-75	35-65	85-100	70-90
Altura en cm	10	50	30	100	5ó35	40

Fisiografía.--Dadas las características de los vientos, la fisiografía tiene especial importancia tanto a nivel regional como local. En el paisaje de las mesetas pueden encontrarse varios tipos de serranías, volcanes y mantos basálticos, extensas depresiones endorréicas y grandes valles transversales (O-E) correspondientes a los principales ríos de la región. Alrededor del meridiano 71°O entre las mesetas y la Cordillera se extiende un paisaje glaciar de grandes morenas y depósitos glaci-lacustres; este relieve ondulado coincide, en parte con la estepa graminosa de Festuca pallescens, de alto valor forrajero. A nivel regional los grandes lagos cordilleranos y los valles transversales ambos orientados según los paralelos, actúan como verdaderos túneles de viento al igual que muchas depresiones endorréicas orientadas en el mismo sentido; los niveles mesetiformes tampoco representan obstáculo a la acción del viento. A nivel local el gran número de pequeñas depresiones sin agua permanente, la orientación de los cañadones a barlovento de los focos de erosión y los filos transversales al viento son rasgos que deben analizarse en detalle para la evaluación de la actividad y peligrosidad de los procesos eólicos. Para la erosión hídrica tienen importancia el tipo de relieve, la altitud y la inclinación y orientación de las laderas. La presencia en superficie de sedimentos de textura gruesa poco consolidados, la salinización generalizada, la alta proporción de arenas mezcladas con los mantos de rodados y con los depósitos glaciares y algunos materiales volcánicos muy livianos (pómez) constituyen una fuente de material abrasivo que, puesto en marcha por el viento, activa explosivamente los focos de erosión que encuentra en su camino. Los depósitos de textura fina compactados y salinizados (playas y fondos de depresiones) son afectados por la erosión hídrica pero también por la deflación; los suelos de alto contenido en materia orgánica de las vegas y llanuras aluviales o de las morenas en la zona de ecotono bosque-estepa, son muy susceptibles a ambos procesos.

Pastoreo.--En toda la Patagonia se practica el pastoreo continuo (0,5 a 3 animales/ha); en la zona costera y central los animales permanecen todo el año en los mismos campos mientras que en el Oeste se utiliza una rotación entre los campos de altura (veranadas) y los campos bajos (invernadas) con la movilización masiva de las majadas. Por otra parte en diversos momentos del año se producen concentraciones de animales relacionadas con las faenas propias del manejo del rodeo. La vegetación y la superficie del suelo son afectadas de 3 maneras: por ramoneo y pastoreo; por pisoteo y por denudación completa (dormideros, potreros de aparte). Cada una de estas acciones produce respectivamente cambios en la estructura y composición florística de la vegetación; descalce, tallado y arrancado de plantas; pulverización de la superficie; excavación; desmoronamientos y deslizamientos. El conocimiento de los hábitos de los ovinos y de los métodos de manejo son de gran importancia para el relevamiento y evaluación de los procesos erosivos pues permite determinar los grados de sobrepastoreo, detectar los estadios iniciales del deterioro y prever la aparición o distribución de

ciertas formas. Todos los factores hasta aquí descriptos son interdependientes, actuando en conjunto con intensidad variable sobre el frágil equilibrio del ecosistema patagónico. A pesar de ello es evidente que el sobrepastoreo es el principal desencadenante -y un eficiente acelerador- de los procesos de erosión tanto eólica como hídrica.

CLASIFICACION DE LAS FORMAS DE EROSION

Las formas más comunes y los paisajes en los que tienen mayor incidencia y desarrollo son:

Procesos eólicos

Acumulación dominante.--Microacumulaciones (fig. 2; en mesetas, terrazas, planicies aluviales); macroacumulaciones (a sotavento de taludes y escarpas basálticas); médanos estabilizados por gramíneas (mesetas altas, muy raros); barkhanes (laderas de valles).

Figura 2.--Microacumulaciones en estepa arbustiva, centro-oeste patagónico. (45°S-71°O).

Deflación dominante.--Pavimentos de rodados (fig. 3; en mesetas, terrazas, filos); playas de denudación (lagunas y depresiones); costras (área glaciar, vegas, planicies aluviales, depresiones); manchones (áreas denudadas en vegas y llanuras de inundación salinizadas); excavaciones (caminos paralelos al viento); esculturas (bordes orientales de lagunas y lagos).

Acumulación-deflación.--"Lenguas de erosión" (paisaje glaciar, mesetas, valles y depresiones).

Procesos hídricos y gravitaciones

Erosión laminar (precordillera, badlands, afloramientos rocosos); en surcos (área glaciar, precordillera); en cárcavas (vegas, planicies aluviales, área glaciar); reticular (mesetas altas); solifluccíón (área cordillerana); ríos de barro (depresio-

Figura 3.--Pavimento de rodados. 52°S-72°O.

nes endorréicas); deslizamientos semilunares (área glaciar); deslizamientos por socavación y derrumbes (cañadones, laderas, taludes).

Procesos de origen mixto (viento, agua, uso)

Las combinaciones de formas más comunes son: cárcavas/lenguas; lenguas con pavimentos y costras/surcos y cárcavas; sobrepastoreo/microacumulaciones, manchones y erosión reticular; pisoteo/esculturas, deslizamientos semilunares, surcos; dormideros/ deslizamientos semilunares y lenguas; caminos, excavaciones y construcciones/lenguas; incendio/lenguas, microacumulaciones.

De las formas eólicas las que afectan mayor superficie son las microacumulaciones pero las más graves y activas son las "lenguas de erosión" (Monteith 1969, Movia 1972) formas triangulares o alargadas de ancho constante con la punta de avance hacia el Este formada por médanos activos (fig. 4). Hacia la zona de origen en cambio, predominan los pavimentos y costras (deflación); su tamaño es variable pudiendo llegar a los 50 km de largo por 400 m de ancho. La velocidad de avance oscila entre los 500 m y los 2 km/año dependiendo del material, la topografía y la vegetación. Las particularida-

Figura 4.--Médano frontal de una lengua arenosa (42°S-72°15'O), viento 90 km/h.

des más llamativas de estas formas son: la dirección constante hacia el Este, la falta de ensanche y la capacidad de ascender laderas y atravesar cañadones perpendiculares a su avance; existen lenguas totalmente arenosas y otras en las que predominan los pavimentos pedregosos y las costras limo-arcillosas con cárcavas.

Entre las formas hídricas las más graves y numerosas son las cárcavas, especialmente las que se desarrollan en las vegas, en las planicies aluviales y en las lomas morénicas entre los 350 y 600 mm de lluvia (campos de Festuca, fig. 5); muchas de ellas son puntos de origen de lenguas de gran tamaño.

Figura 5.--Cárcavas y surcos producidos por pisoteo; en primer plano sobrepastoreo. Area glaciar (52°S-72°30'O).

Evaluación de la gravedad

La escala de gravedad se basó en la combinación de tres factores, con 3 grados de intensidad cada uno (Monteith op.cit.: baja=1, media=2, alta=3) los que pueden variar en función de la escala del relevamiento, el material utilizado y el tipo de erosión. La suma de las intensidades de los 3 factores indica la gravedad: 3-4 leve, 5-6 moderada, 7-8 severa, 9 grave. Los factores considerados fueron: a) tamaño y/o densidad de las formas/cm^2 de mapa; b) valor del campo según tipo de vegetación no degradada (semidesierto=1,estepa arbustiva=2, estepa graminosa y vega=3); c) aspecto fotográfico (forma-tono-textura; indicación indirecta de la actividad) o velocidad de avance.

INVENTARIO

Sus principales objetivos fueron la descripción y clasificación de las formas de erosión hídrica y eólica, su cartografía, la medición de las superficies y la estimación de la gravedad actual de los procesos. La detección de indicadores de las etapas iniciales del deterioro, la evaluación de la actividad, el planteo de posibilidades de vigilancia continua (monitoring) y la actualización periódica de la información se incluyeron en algunas etapas del relevamiento. Además de los problemas ya mencionados de extensión y acceso y la escasez de informaciones básicas, debe recordarse que la mayor parte de la vegetación no es visible en las fotos aéreas ni en el LANDSAT; este hecho implica el uso de una metodología de foto-interpretación que combine diversas disciplinas y cuyos elementos puedan ser utilizados como indicadores indirectos de la situación existente en el terreno a fin de poder planificar con antelación el muestreo, reduciéndolo al mínimo compatible con la heterogeneidad del sistema, las posibilidades de movilización y la precisión deseada.

El inventario se llevó a cabo en varias épocas (1972-74, 1976 y 1978) y a dos niveles de percepción (Long 1968): A) de reconocimiento en escala 1:100.000 (fotografías aéreas y terreno; 30.000 km^2) y B) exploratorio o esquemático en escala 1:1.000.000 (LANDSAT, sobrevuelo y terreno; 600.000 km^2).

Nivel de reconocimiento

El inventario se comenzó en las tres áreas-piloto del Programa INTA/FAO ya citado, paralelamente con la cartografía de los Land Systems. Las tres áreas, representativas de los principales ambientes pasturiles de la Patagonia semiárida,cubren aproximadamente 10.000 km^2 cada una y se hallan en el centro-oeste de la región a los 41°, 45° y 52°S; cuentan con cobertura aerofotográfica 1:40.000, cartas geológicas 1:200.000, estudios sobre estructuras y funcionamiento de la vegetación (Soriano 1956a, 1956b, 1952, 1959 y otros) y ensayos sobre contención de médanos (Castro y Brun 1964). En las 3 áreas los pasos seguidos fueron:

Fotointerpretación.--En los casos en que se contó con los Land Systems éstos se usaron como mapa-base sobre el que se volcaron las diferentes formas de erosión mapeadas por el método de los elementos-patrón (Buringh 1960); cuando no se contó con esta información se utilizó el método de fotointerpretación fisiográfica (Goosen 1967) combinado con los datos de vegetación. La interpretación se efectuó sobre los fotogramas 1:40.000, (fig. 6) y fotomosaicos no controlados 1:100.000; con estereoscopios de espejos (Wild y ODSS II), la transferencia de informaciones de foto a mapa se hizo por calco directo y los cambios de escala por medios mecánicos. En el mapa-base se indicaron todas las formas de erosión, los paisajes y sus subunidades, los posibles tipos de vegetación, el sistema de drenaje, la infraestructura vial y los alambrados, construcciones y poblaciones. Con estos datos se planificaron los recorridos terres-

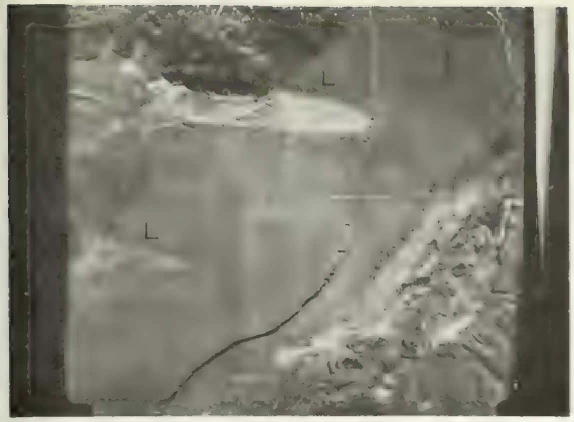

Figura 6.--Aspecto de una lengua en las fotografías 1:40.000 (reducida).

tres, se ubicaron las áreas de muestreo intensivo (áreas-testigo) para la descripción y clasificación de la erosión y de la vegetación y se localizaron transectas para el estudio de los límites entre unidades, la descripción de los ecotonos y la correlación entre datos de terreno y representación en las aerofotografías. Las áreas-testigo fueron elegidas por su representatividad en cuanto a los procesos erosivos y a los rasgos del ambiente y fueron mapeadas en detalle (1:20.000) antes del viaje a campo; su número y superficie variaron según la heterogeneidad del sistema (alrededor de un 3% de cada paisaje).

Control terrestre.--a) Areas-testigo: descripción y medición de las formas de erosión, evaluación de la actividad a través de indicadores indirectos (vegetación y superficie del suelo), descripción y clasificación de la vegetación dentro y fuera de las áreas erosionadas (caractéres estructurales y lista de especies con dominantes), evaluación del sobrepastoreo. Paralelamente se realizaron encuestas entre pobladores, mediciones de la velocidad del viento (anemómetros totalizadores de cazoletas), herborización, toma de muestras de la superficie. Para asentar los datos se usaron grabadores y planillas impresas a las que se agregaron diagramas y perfiles de vegetación (Dansereau 1951, modificado), fotos simples y estereoscópicas y otras observaciones generales. b) Transectas de tipo fito-topográfico; se analizaron las relaciones entre fisiografía-erosión-vegetación en función de su visibilidad en las aerofotografías; asimismo se estudiaron los cambios en los límites de las grandes formas y la ubicación y extensión de los ecotonos a fin de posibilitar la posterior extrapolación de las informaciones en gabinete. La gravedad se estimó en el terreno (para cada área-testigo) y luego se evaluó en los fotogramas según la escala ya mencionada.

Reinterpretación y análisis de datos.--Nuevamente en gabinete se analizó toda la información de campo, se reclasificaron las formas y ajustaron los límites, se definieron los tipos de vegetación y el valor del campo. Con respecto a la velocidad de avance de las lenguas, en algunas zonas se compararon fotografías de distintas épocas y se usaron los datos de los pobladores. Se reinterpretó el material fotográfico y se preparó el mapa definitivo (1:100.000) midiéndose las superficies con planímetro (fig. 7).

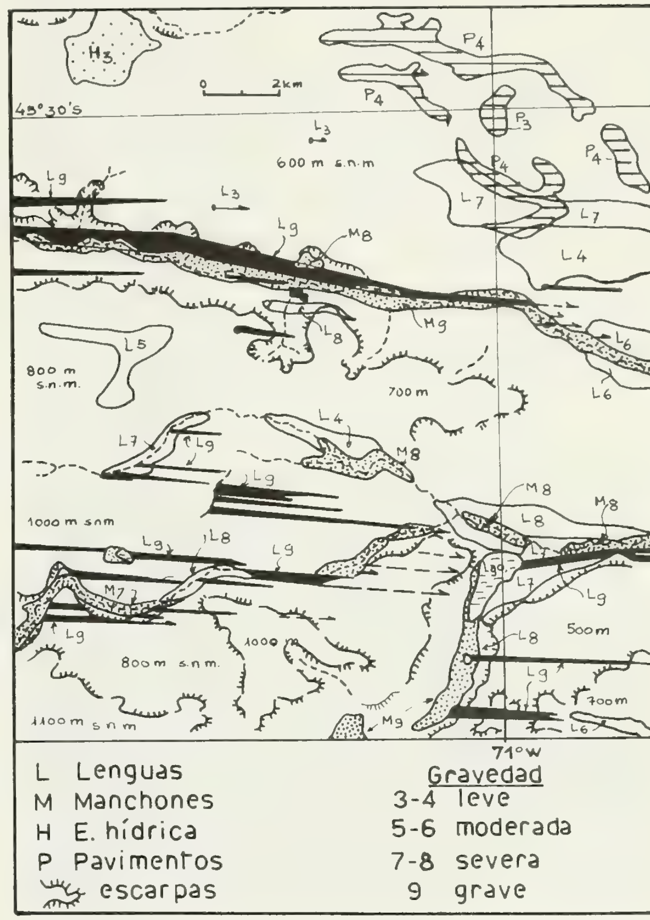

Figura 7.--Sección del mapa de erosión en escala 1:100.000 (reducido).

Nivel exploratorio o esquemático

El inventario se realizó en dos etapas, la primera (1969) utilizando vuelos a baja altura, fotos aéreas y recorridos terrestres y la segunda (1978) con imágenes LANDSAT; ambos mapas con escala final 1:1.000.000. Los antecedentes se reducían a un mapa generalizado de erosión en escala muy pequeña (Auer 1951), mapas parciales de Cappannini y Auer (1957) y de Castro (1965) y parte de la cartografía de las áreas-piloto.

Primera etapa.--El mapa fue realizado por Monteith et al.(1969) con 60 horas de sobrevuelo volcando los datos en cartas topográficas 1:500.000 por medio de símbolos

y números; el control se efectuó con una recorrida terrestre de 30 días (15.000 km) y con fotoanálisis expeditivo en las reducidas áreas con fotocobertura; la gravedad fue estimada durante el vuelo y en el terreno según la escala ya citada.

<u>Segunda etapa</u>.--Con las imágenes LANDSAT se practicó un ajuste del mapa anterior; se analizaron en forma visual las bandas 4, 5 y 7 y posteriormente falso color, en escala 1:1.000.000 y 1:500.000 de dos años sucesivos, y se utilizaron los relevamientos a mayor escala como controles. Para la identificación de la erosión se emplearon preferentemente las bandas 4 y 5; para la vegetación, el sobrepastoreo, los incendios y los rasgos culturales la banda 5; para la información fisiográfica (relieve, salinidad, agua) la 7 y 5 (Movia y Holvoet 1976); el falso color no implicó mayor precisión pero sí más facilidad y rapidez en el análisis. De todas las formas de erosión sólo son claramente visibles las lenguas, aún las más pequeñas; con ciertas restricciones pueden detectarse los desiertos, los grandes pavimentos de rodados y las costras en mesetas y fondos de valle respectivamente; las vegas y llanuras de inundación degradadas y los potreros sobrepastoreados (fig. 8).

Figura 8.--Parte de una imagen LANDSAT en la que se observan lenguas de erosión y pavimentos; 1:1.000.000 (reducida).

Las lenguas se clasificaron por longitud y densidad/cm^2 de mapa (escala 1:1.000.000, fig. 9), valor del campo y visibilidad; la velocidad de avance se obtuvo por comparación entre imágenes de distintas épocas. Además se eligieron dos áres-testigo en las que se compararon fotos aéreas, datos de campo y LANDSAT a fin de evaluar la precisión del mapeo en este último material (Movia 1978).

Las formas incipientes de erosión, las etapas iniciales del deterioro y la reactivación de superficies semiestabilizadas no son detectables en ninguno de los materiales utilizados por lo que su estudio debe ser efectuado en el campo utilizando la vegetación como indicador de la desertización.

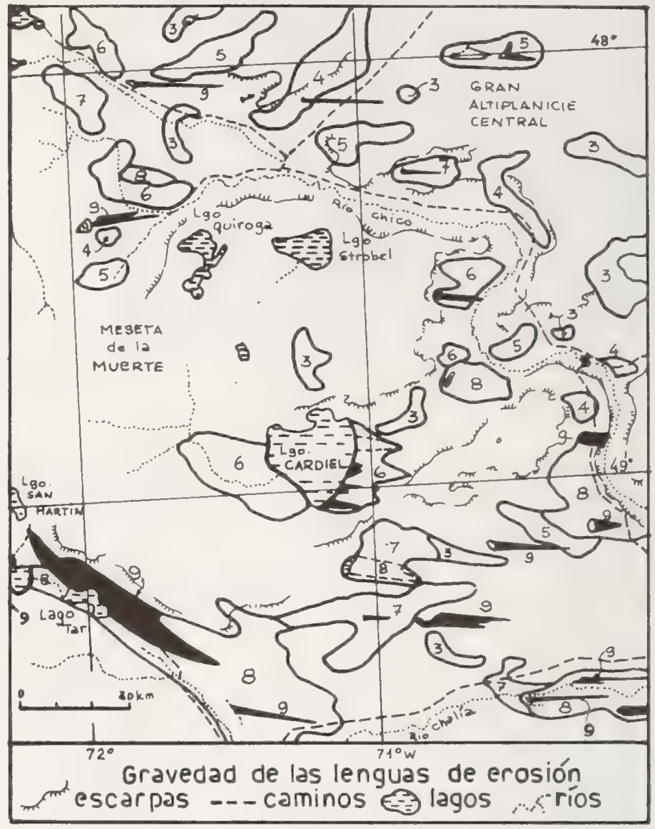

Figura 9.--Sección del mapa en escala 1:1.000.000 con LANDSAT (reducido).

CONCLUSIONES Y POSIBILIDADES FUTURAS

En la experiencia patagónica, los conocimientos adquiridos sobre la distribución y la dinámica de algunas de las formas de erosión y sobre la estructura y función de la vegetación así como las posibilidades que ofrecen las actuales imágenes LANDSAT y los nuevos vuelos fotogramétricos permiten plantear una metodología de inventario que responde a las condiciones técnicas, económicas y físicas de la región y que es lo suficientemente flexible como para proveer información tanto a nivel regional como local.

Las claves fundamentales pueden resumirse en: 1) uso de imágenes 1:500.000 para las etapas exploratorias (provincias, departamentos) y ampliaciones hasta 1:100.000 para las áreas-testigo; bandas 4, 5 y 7 y falso color; mapas finales 1:500.000 y 1:200.000; 2) fotografías aéreas en escalas 1:30/50.000 para el control de las áreas-testigo y en las zonas con problemas en el análisis; también se usarán para los relevamientos a mayor detalle de zonas con problemas particulares (planes de control de médanos, manejo de

cárcavas y áreas denudadas, riego); 3) formación de equipos interdisciplinarios para la fotointerpretación inicial y el campo (por lo menos geomorfólogo y ecólogo); 4) fotointerpretación integrada (fisiográfica y elementos-patrón) asociada a datos sobre vegetación, clima y suelos; 5) profesionales con experiencia en fotointerpretación y análisis visual LANDSAT; 6) planificación previa del trabajo terrestre para reducir al mínimo el muestreo y las recorridas en el campo sin perder representatividad; 7) máximo aprovechamiento del trabajo de campo con una sola campaña y varios equipos trabajando simultáneamente (1 profesional y ayudantes); 8) conocimientos sobre los hábitos de pastoreo y manejo del rodeo (evaluación del sobrepastoreo).

La instalación en Argentina de una antena receptora del LANDSAT y de la estación terrena de procesamiento automático de datos (1980) abre nuevas perspectivas para la actualización periódica del inventario y la posible vigilancia continua (monitoring) de los procesos más activos. La Comisión Nacional de Investigaciones Espaciales (CNIE) y la Facultad de Agronomía de Buenos Aires han comenzado a colaborar en el desarrollo de las bases para la clasificación automática de los datos utilizando toda la experiencia terrestre ya adquirida.

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Multiple Resource Inventories - Evaluation in an Academic Atmosphere[1]

Charles O. Minor[2]

Abstract.--Development of a system for inventorying range, timber, water, and wildlife resources in a single visit is described. Information was required for preparation of multiple resource management plans in a semester-long student exercise. The evolution of methods for collecting this necessary data in the most efficient manner is an on-going process. Nine years experience is reviewed.

INTRODUCTION

In 1971 the School of Forestry, Northern Arizona University, initiated a new, radical curriculum in forestry at the undergraduate level. Included are three semesters of integrated forestry instruction, completely uncompartmentalized and team taught. During the fall semester of the senior year the students cooperatively inventory an area of approximately 50,000 acres (20,000 Ha.) and then individually prepare a multiple resource management plan for the area. It is with the evolution of inventory procedures for the several resources that this paper is directed.

Our semi-arid forests of northern Arizona range from pinyon-juniper, with annual precipitation of 10 to 15 inches (250 to 375 mm.), through Ponderosa pine in the vicinity of Flagstaff, to mixed conifers where precipitation exceeds 25 inches (625 mm.). Resources to be inventoried include (1) forage for domestic livestock (cattle, sheep, horses), (2) wildlife habitat (for both game animals such as elk, deer, antelope, turkey and non-game birds and mammals), (3) watershed conditions (water-yielding areas, flood sources, erosion potential), (4) recreation potential (developed and undeveloped sites), (5) scenic beauty, (6) timber (firewood, pulpwood, sawtimber), and additionally information on protection of the area from fire, insects and diseases.

An attempt will be made to trace the changes in inventory from (1) a general, over-all view, and (2) specific procedures for each resource.

GENERAL

In 1971 very little information was available in the literature regarding multiple resource inventories. We were not sure but what it might be necessary to go over the management unit six or seven times gathering data on each resource separately by techniques then available. Seeking opportunities to collect some information simultaneously we rather intuitively seized upon soils as being a unifying variable. Unfortunately, soil series (or similar) maps were almost totally lacking in our area. Neither did we feel undergraduates could adequately map soil series. So we settled on soil parent material, plus slope and aspect, to a 40-acre minimum, as the basic mapping unit. Fortunately, as might be expected, vegetation boundaries coincided well with soil boundaries. This led us to conclude that timber and forage might be inventoried together; so could wildlife habitat and watershed characteristics, thus perhaps only a couple of passes through the area would be required.

For two years we worked upon the above system, trying to improve the mapping techniques and better relate individual resources to soils and vegetation. Success was only fair, some essential items just didn't fit very well.

About this time we learned of an inventorying system being used in the Lake Tahoe basin which utilized square cells with each cell being characterized by a number of criteria (Tahoe Regional Planning Agency, 1971). The whole data base could be easily computerized and retrieved as needed. At Tahoe 10-acre cells were employed. For the resource values we were working with a much less intensive system was needed, so we went to 100 acre (40 Ha.) cells (31.6 chains square). A cell was characterized for each resource on the basis of 51 per cent, or more, of the cell having that attribute.

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[1]Paper presented at the workshop on Arid Land Resource Inventories. (La Paz, Mexico, November 30-December 6, 1980).
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It was fairly easy to design methods of sampling each cell for each resource--a mechanical grid of points within the cell worked well for timber, forage, water, protection, and recreation, but not so well for wildlife habitat and aesthetics.

We continued to work with and attempt to refine the "cell" system, for some five years. There were numerous advantages, particularly for student use. Cell classification was fairly straight-forward and mechanical with the 51 per cent rule. The cell was small enough to get over, to sample, to study fairly intensively, but at the same time large enough to fit most resource values. A total of approximately 500 cells made for easy sorting, whether by hand or computer.

At the same time, questions and problems continued to arise, some due to increasing resource values, some I think due to the natural evolution and increase in sophistication that comes with continuing to work with a system. There were always concerns about classifying the whole 100 acres on the basis of just over half. What should be done with small, but important different areas within the cell? When combining cells by attributes there were always those individual cells that did not fit, and yet had been classified correctly. Students were bothered by the straight line boundaries of different conditions--they weren't straight lines on the aerial photographs! Why 100 acres? That was too big for some resources and too small for others.

So, we thoroughly reviewed the "cell" approach. We considered reducing cell size as a possible solution, but began to realize that while this might help one or two of the problems, it would merely compound others.

In 1978 we reluctantly abandoned the cells and went back to "polygons." Our basic variable is vegetation--we map "stands" (homogeneous areas of vegetation) whether grass or trees. Each stand is inventoried, using many of the same techniques developed for "cells." Not all problems are yet resolved. For example, from a practical standpoint a minimum stand size is necessary; we use 20 acres. The same questions still arise, on a reduced scale, about what to do with the small (less then 20 acres), but important, distinctly different stands! Polygons are more difficult to handle in the computer. We don't have good digitizing or computerized mapping ability, so have to be content with data retrieved by stand number.

TIMBER RESOURCE

Not many changes have occurred in gathering timber management data. As the Southwest has gravitated to even-aged management, we've substituted age class for size class. We've always used point sampling (usually BAF 20) for basal area and site index for height, applied first to an empirical yield table, now in a computerized stand model to produce present and future volumes. When sampling cells, points were selected in a mechanical pattern, now in sampling polygons one or more random lines are run through a stand measuring points at intervals proportional to stand size.

RANGE RESOURCE

Its been found very feasible to sample for range forage concurrent with the timber inventory. Range condition and potential carrying capacity are determined by the "climax" method (Stoddart et al, 1975) for each unit (formerly cell, now stand). Normally paced transects are established while traveling between timber sample points. Since we're attempting to establish only a preliminary "tentative grazing capacity," this method has given excellent and consistent results.

WILDLIFE HABITAT

This resource has proved difficult to assess. Good conditions for one animal may be adverse for another. From our early attempts to measure and tally specific plants, densities, arrangements, etc., we've instead learned that data collected about other resources (timber, range, watershed) may be of most value in evaluating habitat. Now we map concentrations of browse plants, forage consumed, map obvious travel routes of big game, map any specific high use areas, but no longer attempt to measure or tally anything!

WATERSHED DATA

Securing usable information about runoff, water yields, erosion potential, flood source, flood damage, especially as affected by treatment, has consistently been most difficult to obtain. Watershed managers seem unable or unwilling to even speculate on quantitative values.

We started out with the old "universal soil loss equation," tried mapping critical or susceptible areas, ignored everything but severe erosion, and now are back to recording slope, total cover density, hydrologic soil group to give us USDA SCS "numbers" (SCS, 1964) for each stand to rate same as to water yield or erosion potential.

RECREATION RESOURCE

Our efforts at inventorying the outdoor recreation resources of an area have come nearly full circle. Our original procedure was to locate present and potential sites on the area and record access, capacity, use, and potential for expansion. This was done as a separate operation, not combined with evaluation of any other resource.

In our constant search to develop multi-resource inventories we developed a suitability scale for recreation which could be completed for

each 100-acre cell. This involved a rating of some 12 items ranging from accessibility (distance to road, distance to service facilities etc.) physical factors (potable water, slope, aspect, crown cover, etc.) to scenic interest items. The scale proved very useful and accurate, not difficult to complete, and very consistent in application. The only problem, as should have been anticipated, was that 90 per cent of the cells fell in the same suitability class. About ten per cent ranked higher due to some unique characteristic and justified further consideration. This we already knew, and had mapped under the original system. So, after several year's experience with rating scales, we're back to mapping present and potential sites.

SCENIC ZONES

Since 1974 we've been establishing "landscape control points," (Litton, 1973) along major roads, near water sources, within recreation sites, and around any other areas of scenic beauty. As few forestry students are artists, they use series of panoramic photos, marked as necessary, with accompanying remarks and prescriptions. This operation is usually combined with the recreation mapping, but is separate from the stand by stand inventories previously described.

PROTECTION

Fire hazard and fire risk have always been recorded by unit (cell or stand) into simple and broad classes based upon probability of ignition and fuel quantity, distribution, arrangement, and topography. In addition the location and nature of any insect or disease outbreaks, windthrow, animal damage or other damaging agents are mapped and recorded.

SUMMARY

An attempt has been made to trace the changes in methodology in a multiple resource inventory system over a nine-year period. To recap, our general approach (form of stratification) has gone from polygons based upon soils, to square cells, to polygons based upon vegetation. Discussions with several companies or agencies have indicated the same evolutionary pattern.

Our methods of gathering information on individual resources have undergone similar revisions. In summary, at present timber, forage, watershed, and fire hazard and risk are sampled and recorded on a "stand" basis. Wildlife habitat and insect, disease or other damage are mapped within the stand. Recreation (present or potential sites) and scenic areas (landscape control points) are mapped separately, not on a stand basis.

We will continue to investigate, and hopefully improve our multiple resource inventory methods.

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INVENTORIOS DE LOS RECURSOS MULTIPLES--

LA EVOLUCION EN UNA ATMOSPHERA ACADEMICA

El formento de una systema para los recursos del pastizal, la madera, la divisoria de aguas, y la fauna silvestre en una visita soltera se describa. La información fue requerido para la preparacion de los planos del manejo de los recursos múltiplos por los estudiantes durante una terma educativo. La evolucion de los métodos colectar este información de la manera mas eficiente continua. La experiencia de nuevo añas esta entrada.

An Application of Two-Phased Sampling Methods for Determining Sample Intensities in Multiresource Vegetation Assessments[1]

Vernon J. LaBau[2]

Abstract.--In multi-resource sampling, tradeoffs must be made in the number of samples taken to assess the various resources of interest. Some of the considerations for determining sampling intensities are costs of measurements, differing resource sampling variances, and varying allowable resource sampling errors. A multi-resource inventory approach for determining sampling intensities for timber, shrub, and ground vegetation is presented. Tradeoff considerations and examples are are presented.

INTRODUCTION

In the last 6 years, several Federal and State laws have been passed mandating that public land managers and inventory planners conduct multi-resource inventories on the lands for which they are responsible. Legislators have expressed concern that various resource and land managers not assess the same piece of land separately for each resource of interest. Resource interactions are also often of considerable interest to the manager. In this time of tight budgets and fuel and travel limitations, it behooves these managers to cooperate in their inventory efforts, obtaining information for several resources on each trip to the field. The end result will be fewer trips to the field, making less overall impact on the piece of land as well as on budget and other ceilings.

The Resource Conservation Act (PL 95-192) of 1977 and the Resources Planning Act of 1974 (PL 93-378) as amended by both the National Forest Management Act of 1976 (PL 94-588) and the Forest and Range Renewable Resources Research Act of 1978 (PL 95-307) mandate that the Soil Conservation Service and the Forest Service cooperate in vegetation and soils inventories and avoid duplication or overlap of efforts. An example of such cooperative effort exists in interior Alaska where these two agencies, in cooperation with other Federal and State land management agencies, have combined efforts in assessing multi-resource information in the Susitna River basin north of Anchorage. This combined effort has been underway since 1978 and has gone through many growing pains. Agreeing on common sampling designs, data measurement procedures, and measurement criteria necessitated many discussions and compromises.

Two-phase sampling, described in Bickford (1952, 1961), was used in this multi-resource inventory. In the first phase, a stratification was done, delineating a sample of 5-acre points into 34 vegetation strata on color infrared aerial photography (see appendix III). At the second phase, a sub-sample of ground plots was selected from the first-phase sample set. The second-phase plots are visited in the field and vegetation measurements made.

In 1978 and 1979, the sampling intensity (number of aerial and ground plots needed) was determined for the inventory units based on stratification, means, and variances of the timber resource. Plots were taken in non-forest vegetation, but no allowable sampling error standards were specified to determine sampling intensity desired in non-timber vegetation. Sampling errors for variables in the other resource criteria were calculated as they occurred in the timber-based sample.

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[1]Paper presented at the Arid Land Resource Inventories Workshop, LaPaz, Mexico, November 30 - December 6, 1980.

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An extension of this two-phase timber sampling method was implemented during the winter of 1979-80 to determine sampling intensity, given allowable errors associated with pounds of production of forage. When this approach was used, it was possible for the forage sampling intensity calculations to influence the overall sampling intensity for the inventory unit.

METHODOLOGY

Historically, in two-phase stratified sampling, it has been necessary to estimate or derive several input variables for computing timber sampling intensity. A partial list of these is shown in Table 1.

Conducting timber inventories in Alaska with the two-phase sampling method has evolved and been improved upon over the past three decades. Several stratification strategies have been tried and modified. The means and variances for various timber strata are fairly well known or can be estimated with a reasonable degree of accuracy. In the 1980 study, estimates of timber means and variances were applied to 16 timber strata that were considered important.

There had been little or no application of two-phase sampling for estimating forage production in Alaska, except through timber inventories. Therefore, in the summer of 1980 when the decision was made to determine sampling intensity based on forage production, several forage strata variables had to be estimated or computed with little historic information to rely upon. Basically, variables similar to those for timber, shown in Table 1, had to be derived for forage in order to determine forage sampling intensity estimates.

The procedure for developing the forage production estimates for 34 forage strata that were considered important was done in two stages. A limited amount of information was available on production means and variances from forage strata measured in the summers of 1978 and 1979. This information was accepted as the best available and assumed appropriate for the effort.

The second stage required a bit more innovation. For the forage strata that had not been measured during the summers of 1978 and 1979, or for which insufficient data was available, range production experts were asked to provide their best guesses of mean forage production. They were also asked to provide estimates of the range of forage production values that might be expected in each strata. Snedecor's (1961) method of determining the standard deviation from the range of values was used for these strata.

An example of this technique is as follows: the range of values in pounds of production for a saltwater low shrub stratum was estimated by experts to be between 400 and 1300 pounds per acre. A preliminary evaluation suggested that no more than five plots would fall in that stratum in the final allocation. Snedecor's range factor for five plots is .43. The solution for the estimated standard deviation for the saltwater low shrub stratum was .43x(1300-400)= 387 pounds per acre, which was rounded up to 400.

After determining the mean and standard deviation estimates for forage strata, the only variables still undetermined were those relating to costs of measuring forage plots (photo and ground) and the allowable error limits that would be applied to sampling-intensity computations for forage production.

The cost per plot of obtaining the needed forage information from photos was estimated to be about $3.00. This included purchase of the imagery, establishment of the sampling frame on

Table 1.--Estimates needed for determining sampling intensity for two-phase timber sampling, using aerial photo samples at phase 1.

Commercial forest area	Commercial forest growing-stock volume
Estimated proportion in commercial forest land.	Estimated mean volume by each strata (usually in cubic feet).
Estimated proportion of the commercial forest (phase 1) points that would remain commercial forest when ground checked.	Estimated proportion of total sample unit in each strata.
Estimated proportion in noncommercial forest land.	Estimated standard deviation in each stata.
Estimated proportion of non-commercial forest (phase 1) points that would change to commercial forest.	Estimated total area in sample unit.
Estimate proportion in non-forest land (may include water).	An allowable error limit, set either for the total unit estimate of volume, or for some portion of that volume (i.e. per billion cubic feet).
Estimated proportion of non-forest (phase 1) points that would change to commercial forest land.	Estimated cost of a photo plot (phase 1).
Estimated total area in sample unit.	Estimated cost of a ground plot (phase 2), usually weighted over all ground plots whether commercial forest or not.
An allowable error limit set either for the total unit commercial forest estimate or for some portion of that area (i.e. per million acres).	
Estimated cost of a photo plot (phase 1).	
Estimated cost of a ground plot (phase 2), usually weighted over all ground plots whether commercial forest or not.	

the photograph, interpretation, recording, editing, and partial analysis of the phase 1 data. Forage field plot data collection averaged about $800 during the summers of 1978 and 1979. So, it was decided that $3.00 and $800 would be used as cost values for optimizing phase 1 and phase 2 sampling intensity computations respectively. Any changes in costs for increased data collection efforts, would be based on those 1978-79 costs.

The allowable error limits for forage were established after talking with several of the potential data users. Other resource inventory agencies had no national sampling error standards for their inventories. Since little information had been collected on forage in the past, users were willing to accept almost any "reasonable" reliability standard. They generally agreed with using standards somewhat similar to those used in timber volume inventories.

Historically, timber volumes were measured in a way to provide estimates of cubic feet of growing-stock with an allowable error of 10% per billion cubic feet at the 67% confidence level. Reliability estimates were also later derived for the total cubic foot volume, which generally ranged from 5 to 10%, again at the 67% confidence level. It was decided that forage production estimates would be made at the same confidence level, and that scenarios would be evaluated for allowable error limits 5 and 10% of the total forage production statistic, as well as at limits of 5% and 10% per billion pounds of forage production.

Allowable error for forage area still needed to be established. In timber inventories an allowable error limit of 3% per million acres of commercial forest land was the accepted standard. Here again, allowable error limits are expressed at the 67% confidence level. A few test runs were made on some preliminary forage area estimate data. It was decided that the sampling intensity computations for timber volume at 3% per million acres of commercial forest land, which also forced sampling into noncommercial forest and nonforest areas, would assure sampling precision of better than 5% per million acres of forage land. This intensity would also assure reliability estimates for the total forage area statistic at less than 7% at the 67% confidence level.

Having decided on precision standards, several scenarios of sampling possibilities for the multi-resource inventory could be evaluated. Estimation formulae for double sampling with stratification, as displayed in appendix I, were programed into a desk-top computer with paper output. This allowed the user to make several computations with different mean, variance, cost and allowable error combinations. Table 2 displays results of some of the combinations tried.

One of these scenarios involved using standard deviations in the computations larger than those observed in the historic data. The reason for doing this was that some of the standard deviation information was based on strata with up to 50 observations. It was anticipated, however, that sampling intensity computations would result in allocation of 10 or less plots to some strata. Given the smaller sample sizes, it seemed prudent to attempt to emulate the expected increase in strata standard deviations. These increases in estimated standard deviations were based on Snedecor's (1961) table 2.2.2 reflecting relative sampling efficiencies and variance/range relationships for increasingly larger numbers of sample size (n). Wherever it was anticipated that n for a stratum would be less than 10, given that standard deviation estimates came from historic data where n was greater than 10, the standard deviation inflation option was applied.

As an example of how this was applied, one of the timber strata had an estimated standard deviation of 628 cubic feet per acre based on 60 plots measured in other samples. These plots exhibited a range in values from 140 to 1804 cubic feet per acre. In the preliminary evaluation of final plot allocations, it appeared that no more than four plots would fall in that stratum. Snedecor's range factor associated with four plots is .486. Therefore the inflated estimated stratum standard deviation was computed as .486x(1804-140)= 809 cubic feet, which is about 25% more than the original estimated stratum standard deviation for the 60 plots.

This was applied to four of the timber strata, but due to small sample sizes in historic forage strata data, the option was not applied to forage.

RESULTS

Because of the capability of evaluating sampling intensity solutions for the various scenarios displayed in Table 2, it was possible to make some tradeoff decisions as to selection of resource components in which to concentrate sampling. It was predicted that by measuring 214 ground plots and 4,534 photo plots, it was possible to meet all allowable error standards for timber volume and forage production, with the exception of the one forage scenario with an allowable error of 5% per billion pounds of production.

It was encouraging to the users to see that a forage allowable error of 10% per billion pounds of production would also satisfy the allowable error limit of 5% for the total forage production statistic. It was also interesting to note that an increase of 25% in ground plot cost measurement resulted in an optimum sample allocation of two less field plots and about 380 more photo plots.

Table 2.--Results of sampling intensity calculations for three resource components using three timber inventory scenarios, four forage production inventory scenarios, and one increased ground plot cost scenario.

Components	Scenario being evaluated	Number of sample locations called for on: Commercial forest (CFL) strata		Noncommercial forest (NCFL) strata		Nonforest forage strata		Barren land and water		Total all strata	
		Photo	Ground	Photo	Ground	Photo	Ground	Photo	Ground	Photo	Ground
Timber area	Standard; 3% per million acres of CFL	528	53	37	4	3124	316	87	9	3776	382
Timber volume	Standard; 10% per billion cu. ft. volume noninflated standard errors	1057	13	73	1	6252	68	174	2	7556	84
	10% per billion cu. ft. volume inflated standard errors	636	30*	44	2	3750	177	104	5	4534	214
Forage production	10% per billion lbs. of prod.	498	17	34	1	2948	102	82	3	3562	123
	5% per billion lbs. of prod.	1993	68	138	5	11790	405	328	11	14249	489
	10% per total lbs. of prod.	160	6	11	0	946	32	26	1	1144	39
	5% per total lbs. of prod.	640	22	44	2	3787	130	105	4	4577	157
Forage production, increased plot cost	10% per billion lbs. of prod. photo plots = $3 field plots = $1000	551	17	38	1	3261	100	91	3	3941	121

*Indicate strata where estimated standard deviations were inflated to accommodate expected sub-strata sample sizes of less than 10.

In summary, a set of procedures was used here to decide tradeoffs. These are cost effective, practical, and statistically sound "real world" processes. First an evaluation of sampling intensities was made to see which allocation would give the least cost inventory over three resources of interest, utilizing two-phase sampling. That resulted in a recommended mix of 3962 photo plots and 161 ground plots over all forest and forage strata (Appendix II). Next, the reality of having time to interpret only 1651 photo plots at phase 1 was injected into the sampling intensity tradeoff process. This resulted in a mix of 1651 photo plots and 186 ground plots. Finally, in the proportional allocation of the 186 ground plots to the photo strata, several key strata had fractions of plots (less than one) assigned in the allocation. It was decided that the strata were important enough to be sampled. And, since it is necessary to have at least two plots remain in the stratum to obtain variance estimates, three plots were assigned to each strata where proportional allocation had indicated two or less. Most of the plots occurred in the nonforest vegetated areas.

Because of the evaluations using the various scenarios, photo and field measurements were made with a feeling that allowable error criteria were being met for two of the three components of interest. Timber volume and forage production error standards would be obtained with some sacrifice of error in the third component--area of productive land. Appendix III shows an example of the sampling intensity workup for the forage component. The allowable error criteria were set at 10% per billion pounds of forage and that equated to 5.7% for the total forage production estimate.

This final allocation resulted in 1651 photo plots and 182 ground plots. Forty-eight ground plots would be required in forest strata, but only 90 of the 134 nonforest and water plots would need field measuring. This combination would satisfy volume sampling allowable error limits of ±10% per billion units of forage or timber unless one chance in three occurred in sampling.

CONCLUSION

The techniques and procedures applied here have general utility nearly anywhere, but are especially useful and applicable in two-phase inventories of multi-resource strata for which strata statistics are not available. Such is the case in most arid areas being inventoried for the first time, or where stratified two-phase sampling is being used for the first time.

The two-phase sampling approach is very cost efficient in the more remote forest and arid areas of the world if a significant amount of variation in the estimates can be confined to specific strata on remote sensing imagery. When inventorying remote arid forest lands, these techniques are especially appropriate to assure cost effectivness in multi-resourse sampling via use of multi-level remote sensing materials. If strata statistics are not available, as is often the case, the procedures explained here can provide the planner with the methodology to implement a sampling system that is at the same time practical, logical, and cost effective. If strata statistics are available, the procedure presented here can still be used to evaluate the tradeoffs that need to be considered when simultaneously sampling several resource components in arid lands inventories.

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RESUMEN

En el muestreo de recursos múltiples se deben hacer intercambios de información al evaluarse los diferentes recursos de interés. Algunas de las consideraciones para determinar la intensidad del muestreo son los costos de las medidas, las fluctuaciones en el muestreo de recursos, y los variados errores permisibles en el muestreo de los recursos. Se presenta un enfoque para inventario de múltiples recursos para determinar la intensidad de muestras de madera, arbustos, y vegetación del suelo. Se presentan razones y ejemplos para hacer intercambios.

Summary of commercial forest area and growing-stock volume sampling intensity formulae for use in two-phase sampling.

Number of plots for area sampling

(a) Number of ground locations (all land classes), assuming the number of photo points is not fixed-phase 2.

$$N_a = \frac{\Sigma p_h(p_{h_j}\, q_{h_j}) + \sqrt{\Sigma p_h(p_{h_j}\, q_{h_j})\left[\Sigma p_h(p_{h_j}{}^2) - (\Sigma p_h p_{h_j})^2\right](C_p/C_g)}}{S_{\bar{\bar{x}}_a}{}^2}$$

(b) Number of photo points (all land types)-phase 1.

$$M_a = \frac{\Sigma p_h(p_{h_j}{}^2) - (\Sigma p_h p_{h_j})^2}{S_{\bar{\bar{x}}_a}{}^2 - \left[\dfrac{\Sigma p_h(p_{h_j} q_{h_j})}{N_a}\right]}$$

(c) Number of ground locations (all land types)-phase 2. assuming the number of photo points (M_a) is fixed.

$$N_a = \frac{\Sigma p_h(p_{h_j}\, q_{h_j})}{S_{\bar{\bar{x}}_a}{}^2 - \left[\dfrac{\Sigma p_h(p_{h_j}{}^2) - (\Sigma p_h p_{h_j})^2}{M_a}\right]}$$

(d) Number of ground locations in each strata-phase 2.

$$N_{a_h} = N_a p_h$$

Number of plots for volume sample

(a) Number of ground locations (all land types), assuming the number of photo points (M_v) is not fixed-phase 2.

$$N_v = \frac{\Sigma p_h(s_h{}^2) + \sqrt{\Sigma p_h(s_h{}^2)\left[\Sigma p_h(\bar{x}_h{}^2) - (\Sigma p_h \bar{x}_h)^2\right](C_p/C_g)}}{S_{\bar{\bar{x}}_v}{}^2}$$

(b) Number of photo points (all land types)-phase 1.

$$M_v = \frac{\Sigma p_h(\bar{x}_h{}^2) - (\Sigma p_h \bar{x}_h)^2}{S_{\bar{\bar{x}}_v}{}^2 - \left[\dfrac{\Sigma p_h(s_h{}^2)}{N_v}\right]}$$

(c) Number of ground locations (all land types). assuming the number of photo points (M_v) is fixed-phase 2.

$$N_v = \frac{\Sigma p_h(s_h{}^2,}{S_{\bar{\bar{x}}_v}{}^2 - \left[\dfrac{\Sigma p_h(\bar{x})^2 - (\Sigma p_h \bar{x}_h)^2}{M_v}\right]}$$

(d) Number of ground locations in each strata-phase 2.

$$N_{v_h} = N_v p_h$$

Where:

N_a = The total number of ground locations on all land types needed to meet area error limits - phase 2.

N_v = The total number of ground locations on all land types needed to meet volume error limits - phase 2.

M_a = The total number of photo points on all land types needed to meet area error limits - phase 1.

M_v = The total number of photo points on all land types needed to meet volume error limits - phase 1.

N_{v_h} or N_{a_h} = Number of ground locations in each strata

p_h = Proportion of photo points estimated to be in the h^{th} strata

s_h = Standard deviation of volumes of the h^{th} photo strata sample.

$\bar{x}_h$ = Mean of volumes of the h^{th} photo strata sample.

p_{h_j} = Proportion of photo points classified in the h^{th} strata that are expected to fall in j^{th} strata upon ground classification.

q_{h_j} = Proportion of photo points classified in the h^{th} strata that are not expected to fall in the j^{th} strata upon ground classification.

$$(q_{h_j} = 1 - p_{h_j})$$

$S_{\bar{\bar{x}}_v}$ = Standard error of the mean volume ($\bar{\bar{x}}_v$)

$$S_{\bar{\bar{x}}_v} = AE_v \times (\,p_h \bar{x}_h)$$

$S_{\bar{\bar{x}}_a}$ = Standard error of the area proportion ($\bar{\bar{x}}_a$)

$$S_{\bar{\bar{x}}_a} = AE_a \times (\,p_h p_{h_j})$$

AE_v = Allowable volume error

$$AE_v = (SE_v)\sqrt{\frac{1{,}000{,}000{,}000 \text{ feet of volume}}{\text{Unit volume in feet}}}$$

AE_a = Allowable area error

$$AE_a = (SE_a)\sqrt{\frac{1{,}000{,}000{,}000 \text{ acres}}{\text{Unit area}}}$$

SE_v = Resource Evaluation's (Forest Survey) volume sampling error limit .1 (source = 10% per billion unit feet of growing stock)

SE_a = Resources Evaluation's (Forest Survey) area sampling error limit .03 for commercial forest land (source = 3% per million acres of commercial forest land)

= .1 for noncommercial forest land (source = 10% per million acres of noncommercial forest land)

C_p = Cost of interpreting a photo plot (= \$3.00 each)

C_g = Cost of measuring a field location, weighted over all land class locations (= \$800 each)

APPENDIX II EXAMPLE OF SAMPLING INTENSITY WORKUP FOR TIMBER COMPONET
WITH PHOTO SAMPLE FIXED AT 1651 POINTS

CUBIC FOOT GROWING STOCK VOLUME SAMPLING INTENSITY WORKFORM
(2 Phase Sampling Method)

Table of sampling intensity computations Beluga Unit reinventory. Date 4-29-80
Formula coefficients for use in computing sampling intensity
Computation orientated to a sample error of ± 10 percent per billion cubic feet of growing stock based on a fixed number of photo points (M_v = 1651).

	Photo Timber Strata	Photo Interpretation Number in strata	Prop. P_h	Strata Standard Deviation (Cu. ft.) s_h	Strata Mean (Cu. ft.) x_h	$P_h s_h$	$P_h(s_h^2)$	$P_h\bar{x}_h$	$P_h(\bar{x}_h^2)$	$P_h \times N_v = N_{v_h}$	Contingency	Total Plots
	Productive Forestland (Commercial)											
	-Closed Forest-											
21	Short White Spruce	9	.0054	43	615					1.0	2	3
22	Young Deciduous	0	0							0	0	0
24	Medium Age Deciduous	16	.0097	809*	1194					1.8	1	3
25	Tall White Spruce	8	.0048	354	1450					.9	2	3
26	Old Age Deciduous	72	.0436	844*	1746					8.1	0	8
27	Young Cottonwood	0	0							0	0	0
28	Medium Age Cottonwood	2	.0012	1612	3681					.2	2	2
29	Old Cottonwood Stands	0	0							0	0	0
	-Open Forest-											
31	Short White Spruce	6	.0036	163	128					.7	2	3
32	Medium Aged Deciduous	32	.0194	376	424					3.6	0	4
33	Tall White Spruce	7	.0048	367*	478					.9	2	3
34	Old Age Deciduous	77	.0466	681*	747					8.7	0	9
35	Medium Age Cottonwood	2	.0012	1236	1270					.2	2	2
			.1403									40
	(Noncommercial Forestland-Black Spruce)											
41	Closed Short Black Spruce	11	.0067	259	213					1.2	2	3
42	Closed Tall Black Spruce	3	.0018	250	884					.3	3	3
43	Open Short Black Spruce	2	.0012	446	1008					.2	2	2
			.0159									8
	Nonforest Land	1320	.8274	100	50					153.9	0	154
	Water	38	.0230	0	0					4.3	0	5
	TOTALS	1651	1.000			176.8	77140.1	195.32	212718			207

$$\text{Number of Ground Locations} = N_v = \frac{\Sigma P_h(s_h^2)}{S_{\bar{x}_v}^2 - \dfrac{\Sigma P_h(\bar{x})^2 - (\Sigma P_h\bar{x}_h)^2}{M_v}}$$

= 186 Ground Plots

Number of Locations by Strata $N_{v_h} \times P_h$

Number of locations in all commercial strata = 26.1

Optimum cost solution
Ground Plots: 161 @ $800
Photo Plots: 3962 @ $3.00

Final
Total = 207 Plots

Unit cubic foot total estimate

=3,739,6858 acres x average volume per acre

= " x $\Sigma P_h\bar{x}_h$

= " x 195.32 cubic feet per acre

= 751,251,294 cu. ft. of volume

with 11.5% error for total estimate

* Standard deviations inflated, anticipating small sample sizes.

APPENDIX III EXAMPLE OF SAMPLING INTENSITY WORKUP FOR FORAGE COMPONET WITH PHOTO SAMPLE FIXED AT 1651 POINTS

CURRENT ANNUAL FORAGE PRODUCTION SAMPLING INTENSITY WORKFORM
(2 Phase Sampling Method)

Table of sampling intensity computations Beluga Unit reinventory.
Formula coefficients for use in computing sampling intensity.
Computation orientated to a sample error of ± 10 percent per billion pounds of current annual forage production based on a fixed number of photo points (M_v = 1651).

Date 4-10-80

Photo Code	Photo herbage Strata	Photo Interpretation Number in Strata	Prop. p_h	Strata Standard Deviation (Pounds) s_h	Strata Mean (Pounds) $\bar{x}_h$	$p_h s_h$	$p_h(s_h^2)$	$p_h \bar{x}_h$	$p_h(\bar{x}_h^2)$	$p_h \times N_v = N_{v_h}$	Previously Assigned Plots	Contin-gency	Total Plots
	Productive Rangeland (Commercial Forestland)												
	-Closed Forest-												
21	Short White Spruce	9	.0054	243	1250					.8	3		3
22	Young Deciduous	0	0	250*	1400*					0	0		0
24	Medium Age Deciduous	16	.0097	145	700					1.3	3		3
25	Tall White Spruce	8	.0048	400*	1000*					.7	3		3
26	Old Age Deciduous	72	.0436	215	650					6.1	8		8
27	Young Cottonwood	0	0	250*	500*					0	0		0
28	Medium Age Cottonwood	2	.0012	440*	1100*					.2	2		2
29	Old Cottonwood Stands	0	0	500*	1200*					0	0		0
	-Open Forest-												
31	Short White Spruce	6	.0036	389	1600					.5	2		3
32	Medium Aged Deciduous	32	.0194	560	1400					2.7	4		4
33	Tall White Spruce	7	.0048	200	500					.7	2		2
34	Old Age Deciduous	77	.0466	460	1150					6.5	9		9
35	Medium Age Cottonwood	2	.0012	480*	1200*					.2	2		2
	(Noncommercial Forestland-Black Spruce)												
41	Closed Short Black Spr.	11	.0067	91	260					.9	3		3
42	Closed Tall Black Spruce	3	.0018	30	275					.3	3		3
43	Open Short Black Spruce	2	.0012	240	600					.2	2		2
	(Nonforest Rangeland) -Saltwater Wetlands-												
50	Saltwater Grassland	1	.0006	400*	1000*					.1		1	1
51	Saltwater Low Shrub	6	.0036	400*	1000*					.5		2	[illegible]
52	Saltwater Tidal Marsh	5	.0030	400*	1000*					.4		2	3
	-Shrublands-												
60	Tall Shrub Alder	187	.1133	1100	2750					15.9		0	16
61	Tall Shrub Alder/Willow	40	.0242	600	1500					3.4		0	4
62	Low Shrub Willow/Birch	18	.0109	350	875					1.5		1	3
	-Grassland-												
63	Tallgrass	30	.0182	1300	3250					2.5		0	3
	-Tundra-												
64	Sedge-grass Tundra	7	.0042	400	1000					.6		2	3
65	Herbacious Tundra	81	.0491	400	1000					6.8		0	7
66	Shrub Tundra	69	.0418	390	975					5.9		0	6
67	Mat & Cushion Tundra	106	.0642	200	800					9.0		0	9
	-Freshwater Wetlands-												
68	Sphagnum	37	.0224	118	450					3.1		0	3
68	Sphagnum/Shrub Bog	55	.0333	620	850					4.7		0	5
	All Productive Rangeland		.5456										114
	Unclassified	276	.1672	300*	500*					23.4			24
	Non-productive Rangeland												
70-79	Cultural influence	4	.0007	0	0					.1		3	3
	Barren Nonforest Land												
80	Mud Flats	0	0	0	0					0		0	0
81	Rock	208	.1260	0	0					17.6		0	18
82	Permanent Snowfield	227	.1375	0	0					19.3		0	20
90+	Non-census water	39	.0230	0	0					3.2		0	3
TOTALS		1651	1.000			344.1	245286.8	832.5	1,474,264				182

Final
Total = 182 Plots

$$\text{Number of Ground Locations} = N_v = \frac{\Sigma p_h(s_h^2)}{S_{\bar{x}_v}^2 - \dfrac{\Sigma p_h(\bar{x})^2 - (\Sigma p_h \bar{x}_h)^2}{M_v}}$$

= 140

Number of Locations by Strata $N_{v_h} \times p_h$

Number of locations in all herbage strata = 39.7
(Including unclassified strata)

Optimum cost solution
Ground Plots: 123 @ $800
Photo Plots: 3562 @ $3.00

* Estimated means and standard deviations

Unit pounds of forage production estimate

=3,739,658 acres x average pounds per acre.

= ____*____ x $\Sigma p_h \bar{x}_h$

=3,113,151,225 total pounds of forage production

with 5.7% error for the total estimate.

Time Compaction Analysis[1]

John E.D. Fox[2]

Abstract.--A modified sample plot procedure is described which incorporates time variables in comparatively short-run investigations. Historical records and recent events are used to stratify samples designed to elicit information on the regeneration of the widespread Australian species Acacia aneura. Two examples of natural regeneration studies are given which concentrate on perturbations.

INTRODUCTION

A cost efficient sampling scheme is one which achieves its objectives with minimal financial outlay. The method described is summarised as 'time compaction analysis'. Field exercises have been designed to cover as great a range of variables in the determining parameter as can be found. The test of efficiency is met as costs have been determined by the expedient of simple cash limits, with no recourse to 'overrun', 'inflation allowances' or 'contingencies'.

Prior to outlining the principles involved in selection of study areas it is necessary to briefly describe the vegetation understudy and the general objectives of the research.

Vegetation

Acacia shrublands occupy a quarter of the land surface of Australia. Perhaps the most widespread species is mulga or Acacia aneura (fig. 1). In Western Australia this species occurs mainly in arid/semi-arid regions where average annual rainfall is 250 mm or less. Locally it may comprise the bulk of the perennial woody biomass present, but a number of other species occur within its area of distribution. In an area of 25,000 square miles of inland Western Australia Speck (1963) described 75 different vegetation communities. Of these 70 contained, and many were characterised by, Acacia aneura. These communities interdigitate and tend to follow soil and topographic gradients.

Since settlement this species has provided fence posts, firewood and also source material for producer gas. Pastoral and mining enterprises were dependent on it. Patches of dead mulga are frequently seen throughout the pastoral zone. Death has been attributed to a number of causes and it is by no means clear whether the species may be permanently lost from such areas.

Study Program

From 1975 a programme of research has been in operation aimed at elucidating the influence of factors affecting natural regeneration and growth of Acacia aneura. A complete exposition of these aspects of the biology of a comparatively long lived tree necessitates many years of sustained observations. However funding authorities, quite naturally, are interested in results in the short term. Major constraints to sectors of the programme affecting the selection of study areas include

1. The necessity for area coverage (i.e. use of plots).
2. The desirability of replication and representativeness.
3. Inability to randomise in the office.
4. The need to measure (or count) individual plants.

The majority of the more readily accessible mulga country is grazed by sheep, and has been for much of this century.

SELECTION OF STUDY AREAS

The widespread distribution of mulga provides a large potential land area available for study. The requirement of geographical coverage is met by including studies in the northern, central and southern sectors of the

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[1]Paper presented at the Arid Land Resource Inventories Workshop (La Paz, Mexico, November 30-December 6, 1980).

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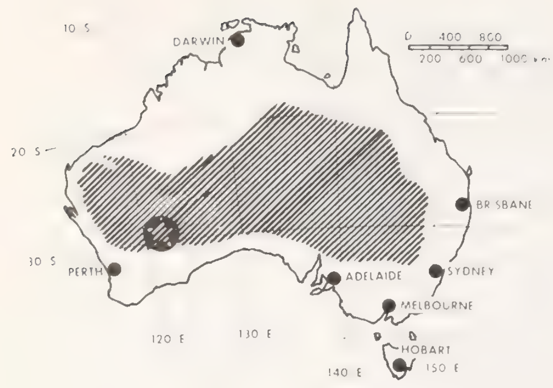

Figure 1. Distribution of Acacia aneura in Australia. Study sites referred to lie in the area indicated by a circled star.

range of Acacia aneura. Within these areas the major criterion for site selection has been the presence of a reasonably well defined perturbation.

Major disturbances studied have included fire, felling, and grazing. More site-specific events have included hailstone damage, localised seedling occurrence, and changes to drainage patterns. Considerable liaison is undertaken with the local pastoralists to ensure that sites studied are

a. easily mappable,
b. readily relocatable,
c. accessible in most weather conditions.

Figure 2. Layout of a standard plot in burnt mulga at Menangina. This area was burnt in January, 1976, the photograph taken 24 months later.

Area Coverage

Rectangular plots of 20 x 25 m aligned in cardinal directions, with corners permanently marked have been developed by an iterative procedure in conjunction with the usual statistical approaches (e.g. Friedel 1977). At establishment this 'standard plot' is subdivided into 5 x 5 m squares with ropes (fig. 2) and steel pins and all perennial plants (plus other features as appropriate e.g. ash, cut stumps) are plotted at a scale of 1:100.

Angle-iron or hardwood posts hammered into the ground can be seen from considerable distances in much of the mulga country.

Replication and Representativeness

Two standard plots are a minimum to adequately sample one stratum. Plot subdivisions (i.e. 20 at 5 x 5 m) provide further detail for analysis if required. In general the practice has been to locate paired plots within reasonable walking distance of each other and where the contrast between them has been greater than anticipated a third (or more) plot has been added.

Representativeness is less easily rationalised. It will be clear however that sites which do not carry mulga are excluded, and that where the obvious criterion of stratification is missing then a plot site must be rejected. Where regeneration levels or current stocking are compounded by irregular and patchy distribution the plot must be accepted as being representative of the area sampled.

Randomisation

For the same reasons that representativeness is often difficult so is it usually impossible to randomise plot locations prior to the first field visit. The usual method adopted has been to drive slowly along the access track, fenceline or whatever observing the general characteristics of the vegetation. When some degree of uniformity appears to have been cumulatively perceived then the vehicle is stopped at a position such that the distance travelled is a multiple of 0.5 or 1.0 km from the last cross fence, mill or bore. Ease of relocation is of great importance, as also is comparatively straightforward access.

The area surrounding a watering point is one level of management unit in pastoral country; this has been described as a piosphere by Lange (1969). To avoid any undue influence of excessive grazing all plots have been sited at least 1.5 km from a watering point.

Distance from the vehicular access location depends on the type of study and the vegetation pattern. In general the nearest corner post is usually at least 100 m from the access track.

Measurements

All individual Acacia aneura plants are

labelled and measured at the time of plot establishment. Height, crown diameter and stem diameter (when measurable) are recorded. Blank plots are rare but when encountered several nearby individuals are usually measured. Other species present are not labelled but are recorded on the plot plan. The density of plants influences the time taken to record the plot, and where individuals (e.g. seedlings) are particularly numerous the method permits a raw count and average heights to be used, provided that a defined area is completed by the standard method.

Soil depth, texture and colour are often useful and rapidly recorded. Observations of grazing on plants, frequency of herbivore scats, insect and disease incidence are also frequently taken at little extra time cost. Concentration of effort on sites exposed to perturbation implies that control plots should also be monitored. So far as possible such are chosen to cover more than one study to maximise the value of such less productive measurements.

EFFICIENT USE OF TIME

The overall programme is field-based and generates two basic costs: travel and days in the field. Internal air travel is costly and vehicles cannot be hired on site. Most studies therefore entail a fixed element of travel cost due to positioning, this is comprised of vehicle hire and unproductive labour costs. Time constraints are imposed by personal availability being limited to out-of-semester periods, and by the requirement for field assistance of necessity coinciding with periods when students can be hired. Obviously therefore a given field period is most productive if a package of studies can be tackled in one trip such that positioning costs are spread and days in the field are utilized as productively as possible. As far as possible rest-days coincide with travel, and each expedition is self contained as regards provisions and equipment. An optimum team size is four persons.

Daily Plans

Individual days are utilized most efficiently by planning to establish or remeasure a string of sample plots in sequence along a circular route of access. On remeasurement visits two or more established sets may be visited in a day, or subsamples only may be measured. It can be seen that subsidiary studies are more likely to be initiated in the locale of pre-existing major studies. To put them in completely new locations would be most inefficient in time costs.

Overall Strategy

It can be seen that in most cases studies have started with concentration on an unusual occurrence. Intrinsic characteristics relating to such can then hopefully be extrapolated to cover the general theme, that is how does _Acacia aneura_ regenerate and how fast does it grow? It is anticipated that 40 years is required. This is necessary to follow seedlings through to mature trees, to take account of weather patterns and to confirm trends identified from the kinds of studies described in the examples which follow. Some studies initiated as short-run investigations may, in due course, evolve into long term programs.

Two types of growth rate may be distinguished: that which occurs under pristine conditions and that following disturbance. The former is rare - even unstocked country carries feral goat, donkey, horse and camel. Nevertheless some examples are available. The examples are both of the latter, in the first case destruction of pre-existing stands by fire and in the second regrowth following severe logging. These illustrate the two main opportunities for time compaction analysis - recent events and well documented historical records.

REGENERATION AFTER FIRE

The generally open nature of the mulga formation led observers to suppose that fire was not of great importance to it (Gardner 1957). However fire is being increasingly recognised as a natural element in most Australian plant communities (Noble et al 1980).

In the summer of 1973-74 unusually heavy rains fell over much of the inland of Australia. As the consequential dense herbage dried off high fuel loads were available and lightning started numerous fires which covered large tracts of country (McArthur and Luke 1977, Luke and McArthur 1978). Some 12 million ha of Western Australia's pastoral country were burnt, mainly by a series of fires to the east and north-east of Kalgoorlie. These fires started in October, 1974 and were still burning in January, 1975 (Fox 1980).

Table 1. _Acacia aneura_ seedlings recorded in height size - classed by months after fire, Menangina.

Fire Set	Months	Numbers in Size Classes (cm)				
		<10	10<25	25<50	50+	Total
A	36	85	102	30	3	220
	42	68	100	46	4	218
	54	30	112	62	34	238
B	24/36	-	13	22	-	35
	30/42	-	7	27	2	36
	42/54	-	3	18	17	38
C	24	29	79	82	25	205
	30	21	83	76	32	212
	42	14	56	73	71	214
D	12	6	-	-	-	6
	18	10	-	-	-	10
	30	2	13	4	-	19

Sampling Parameters

A visit to this area in January, 1976 took place when fire was again burning in mulga country and preliminary observation sites were established near Menangina ($29^0 50$'S, $121^0 55$'E) at that time. Fire again occurred in January, 1977 in the same general area. By January, 1978, when a formal study was commenced, four distinctive strata of disturbance were available for sampling. In addition to areas burnt 1, 2 and 3 years earlier, a tract of land at Menangina had been burnt in January of both 1975 and 1976.

A total of 27 standard plots were established at Menangina using the following criteria for plot selection:

1. Presence of Acacia aneura, at least prior to the fire.

2. Definite evidence of substantial fire damage within the general area.

3. Reliable evidence of the time of fire occurrence.

4. Subjective visual estimate that the plot site was representative of the surrounding landscape.

5. Coverage of all four fire-time strata available.

Areas sampled by fire sets were as follows: A burnt January, 1975, 8 plots, 0.4 ha; B burnt January,1975 and January, 1976, 2 plots, 0.1 ha; C burnt January, 1976, 9 plots, 0.45 ha; D burnt January, 1977, 8 plots, 0.4 ha. The total sample plot area of 1.35 ha is representative of some 700 km^2 sampled, of the order of .00002 percent. Establishment occupied 32 man days and subsequent remeasurements have taken 16 man days.

Results

A total of 509 seedlings of Acacia aneura had

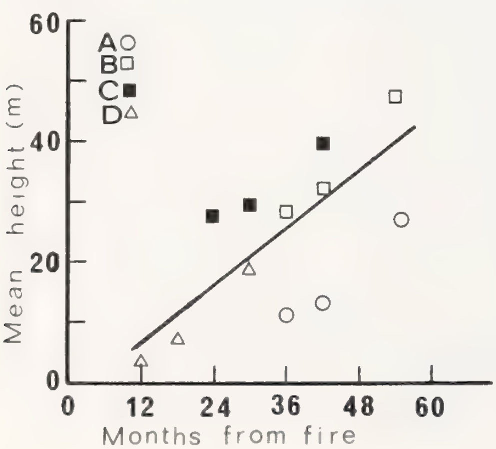

Figure 3. Mean height of Acacia aneura seedlings and time from fire. Data averaged by sets MH = 0.710 Mo - 1.005, r = 0.696 *

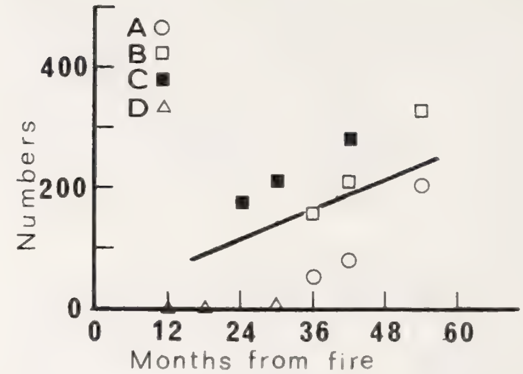

Figure 4. Numbers of Acacia aneura seedlings >30 cm in height per ha and time from fire. Linear regression not significant.

become established by July, 1979 (table 1) and were measured for height. One plot in Set A had a number of additional unmeasured seedlings. Regeneration was evident in all fire sets. Despite problems with Set B viz should it be assumed that seedlings germinated after the first or the second fire? - there is also a definite progression of size with time from fire (fig. 3) and an obvious trend of increasing number of seedlings with time (table 1). The latter is examined further in figures 4, 5 where numbers in Set A have been adjusted and all sets standardised to numbers per hectare. It may be assumed that seedlings of 30 cm and over are well established and likely to persist.

Despite the trend the regression of numbers on time from fire is not significant (fig. 4). If we consider the stocking of seedlings per ha and its relation with mean height there is a much closer relationship (fig. 5) though it cannot be said that stocking depends on height.

An examination of variation at the sub-plot level (5 x 5 m) suggested that seedlings tend to be

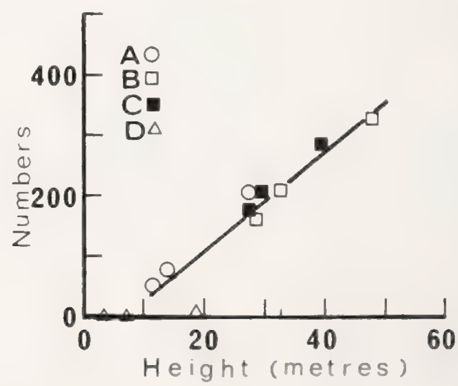

Figure 5. Numbers of Acacia aneura seedlings >30 cm in height per ha and mean height No. = 8.343 MH - 57.272, r = 0.925 ***

more numerous near ash than elsewhere, but that too intensive heat may destroy seed in the ground and insufficient fire may not remove grass competition.

This study continues.

REGENERATION AFTER CUTTING

Timber cutting operations took place in mulga country south-west of Leonora ($28^0 53$'S, $121^0 20$'E) from the turn of the century until the 1960's. The timber was used to supply the Sons of Gwalia goldmine, and cutting was generally systematic and thorough, at least after the establishment of the Western Australian Forests Department, following the Forests Act of 1918.

Sampling Strata

Consultation of old maps and plans suggested that three main areas could be distinguished 1902-9, 1909-38, and 1939-57. Of these considerable detail was available in respect of the latter. A program was commenced in July, 1977 working west and north of Jeedamya ($29^0 24$'S, $121^0 16$'E). A set of 18 standard plots was established in 24 man days. An additional 5 plots were established in 1978 with 4 man days; in 1980 8 of the original plots were remeasured and observations were taken in 2 additional unmarked locations, all in 4 man days. Areas sampled are summarised in table 2. The total area sampled to date is 1.25 ha, from some 1,200 km^2 cut over.

Plot locations were determined by the following criteria:

1. Presence of cut stumps.
2. Vicinity to rail lines.
3. Central position in respect of old plans.
4. Coverage of a range of years from felling.

Table 2. Acacia aneura recorded in height size classes tabulated by year of felling, Jeedamya.

Year of Felling	No. of Plots	Numbers in Size Classes (m) <1	1<2	2<3	3<4	4+	Total
1905	3	2	–	–	–	5	7
1911	3	9	6	1	2	15	33
1930	2	12	10	13	1	5	41
1935-7	5	14	34	19	8	17	92
1940	2	6	4	1	1	9	21
1941-2[1]	4	32	7	5	5	21	70
1943[1]	4	18	14	10	3	8	53
1946[2]	1	6	6	7	2	9	30
1957[2]	1	9	1	10	7	3	30

[1]These 8 plots were measured twice, increments represented by full symbols in fig. 6.

[2]Mean values for these trees are represented by circles in fig. 7 (these were temporary plots).

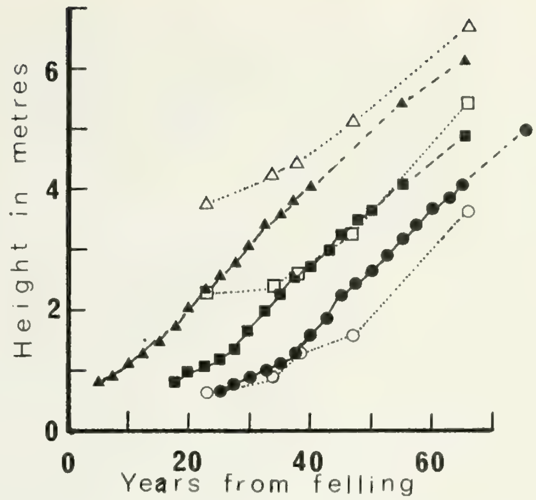

Figure 6. Height/age relationships for felled plots. Full symbols illustrate postulated height for age progression based on 3 year increments 1977-80 for 8 remeasured plots. Open symbols represent mean heights in height classes derived from 11 plots representing 5 age from felling categories. Dotted lines suggest possible progression.

Results

A total of 377 individual mulga have been measured (table 2) and of these 123 have been remeasured. While some caution must be attached to whether individuals grew from seedlings or small trees, and also as to the precise year of felling for the pre 1935 plots, it is indubitably true that

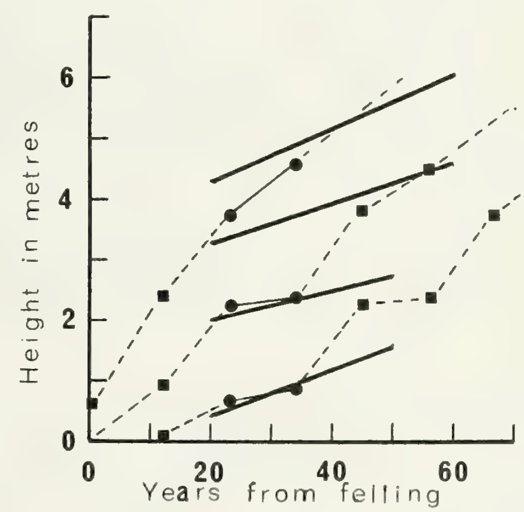

Figure 7. Height/age relationships for felled plots. Circles represent mean heights for three size categories at 23 and 34 years from felling. Squares enunciate trend lines derived from these. Solid lines are regressions of height/age obtained when individuals from all plots placed in broad classes corresponding to those delineated by open symbols in fig. 6. From the top n and r, respectively are 90, 0.59; 58, 0.82; 110, 0.40; 136, 0.57.

regeneration has followed felling in all areas.

It is believed that regeneration of mulga occurs in waves dependent on heavy rainfall. The range of sizes present thus represent several different recruitment periods. Attempts at averaging heights across the 'year of felling' strata were largely unsuccessful. Several approaches are available to estimate growth rates from the data available.

Conservative estimates are shown in fig. 6. The full symbols assume that rainfall 1977-80 gave average growth and that size/growth rates are correlated. There is reasonable agreement when a range of plot data is used to derive curves (open symbols, fig. 6). The temporary plots measured 23 and 34 years from felling were not standard plots and were designed specifically to capture the variability in height present in three specific height classes at each site. These give more optimistic growth rates (dashed lines, fig. 7). Finally summarising all data linear regressions covering the range of ages sampled suggest slower growth rates than the other methods (solid lines, fig. 7).

This study continues. Intermediate data will be added from time to time.

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ANALISIS DE RECOPILACION

Este escrito muestra un costo eficiente de los ejemplos diseñados para cubrir una vareidad de problemas.

La vegetaciòn vista es la porciòn de Western Australia's Acacia, territorio donde el crecimiento de las especies Acacia aneura (mulga) es dominante. Estas especies estàn proporcionadas con fences, madera para fuego y otros materiales para producir energìa. La zona es actualmente usada unicamente para ovejas.

El programa descrito comenzò en 1975. Cubierta geogràfica ha sido completada por cada àrea dividida en sectores. Dentro de los sectores registrados, desòrdenes han sido notados, estos incluyen incendios, derribamiento de àrboles y pasteamiento.

Terrenos rectangulares de 20 x 25m son usados con posibilidad de sub divisiòn si se requiere. Procedimientos para cubrir el àrea, replicaciòn y al azar son dados. Medidas convencionales de àrboles y observaciòn de la tierra son notados. Varios terrenos son examinados en cada visita basados en un plàn estimado de tiempo y distancia econòmicamente. Dos ejemplos de estudios recientes son dados para ilustrar los mètodos usados.

Regeneraciòn despuès de incendios. Despuès de fuertes lluvias en 1973-1974, extensivos incendios ocurrieron en el centro de Australia, en àreas donde el fuego virtualmente era desconocido anteriormente. Un estudio del noreste de Kalgoorlie fuè examinado en 1978 en el cual 4 àreas distintivas "despuès de incendio" eran vàlidos para examinaciòn. Regeneraciòn de la siembra se hizo presente y ambos, nùmero y altura mostraron progreso despuès del incendio. Acacia anuera es capaz de regenerar despuès de incendios.

Regeneraciòn despuès de la poda. Un estudio del àrea sureste de Leonora donde la poda de mulga fuè hecha entre 1905 y 1961 para suministrar una mayor mina de oro, fuè seleccionada para la aplicaciòn de los fundamentos. La alocaciòn de los terrenos fueron seleccionados en la evidencia de restos de àrboles, lìneas del tren y antiguos planos. Curbierta de una extensiòn de tiempo desde la poda, fuè llevado a cabo. Regeneraciòn ha seguido el derribamiento en todas las àreas e informaciòn preliminar en crecimiento, es presentado.

Monitoring Change with Combined Sampling on Aerial Photographs and on the Ground[1]

P. Schmid-Haas[2]

Abstract. Combined inventories with sampling on the ground and on aerial photographs (or other media of remote sensing) can be very efficient. For the assessment of change the sample plots should be permanent. This holds true for the samples on the ground as well as for the samples on the photographs. Methods to establish permanent plots on aerial photographs and permanent ground plots without any visible marking are available.
In view of the enormous, ever increasing, and often uncontrolled influence of man on the vegetation cover of the earth, the author is concerned about practical large area inventories to monitor the dynamic behavior of our ecosystems being largely nonexistent and research to solve these urgent problems being slow.

SAMPLING A STACK OF WOOD OR A DYNAMIC ECOSYSTEM?

The inventory method to be chosen depends on the kind of information required. Possibly the most important question is whether we only need knowledge on the current state of the land resources or have to monitor change. It is often not easy to get a clear answer to this question because in every day life we do not have to answer it: If we have a good knowledge of the new and the old state we also have quite a good knowledge of the difference, and if our knowledge of one of the states is deficient, it will also be the case for the change that has taken place in between. Contrarily, when sampling techniques are used, we have a different situation. There are methods that lead to very valuable static information but their evidence on the dynamic process may be entirely unsatisfactory.

Furthermore, one has to determine, whether information on net changes is required only or whether the components of change, namely: growth, exploitation, and mortality, are also asked for.

For planning the one-time exploitation of a forest by clear-cutting, where a good estimate of the volume of merchantable wood will be necessary, it may not be of interest how the forest developed to reach the present state.

On the other hand, for the cultivation of an ecosystem, information on the current state will not be sufficient. There may be a continuing need to monitor the dynamic response of the ecosystem to man's harvest and regeneration activity.

To check the success of the measures at the end of the planning period it is necessary to know growth as well as structural changes. The main object is to reveal discrepancies between forecast and achievement in time for remedial actions to be taken. Even relatively small overall changes may be important since they show the tendencies. Therefore, the request for information on changes may lead to much higher demands on the inventory than requests for static information. In many cases it will also be necessary to verify by an inventory if and how the planned measures were executed (verification of exploitation).

Where the development of land use is hardly controlled by the government, it is of utmost importance to detect changes as soon and as accurately as possible. Only thereby warning of environmental deterioration may be obtained before it is too late.

For the most part, information on the current state as well as on the changes that have taken place between two inventories will be required. In this case accuracy requirements on current means are often irrelevant because inventories that fulfil the minimum conditions for the estimates of changes will in general give estimates for the current means that are more accurate than necessary. There are no inventory methods that give good information on changes only.

In some countries it is recognized that the dynamic behavior of our ecosystems should be monitored, in a few of them this insight has even led to changes in the inventory methods.

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[1] Paper presented at the Arid Land Resource Inventories Workshop, La Paz, Mexico, November 30-December 6, 1980.

[2] Swiss Federal Institute of Forestry Research, CH-8903 Birmensdorf/ZH, Switzerland.

But in most countries the consequences are not yet drawn. Often the wrong questions are answered with high efficiency.

TEMPORARY OR PERMANENT GROUND PLOTS?

The combination of a relatively small number of permanent plots with a large number of temporary plots will in general be most efficient to estimate current means at successive occasions. Ware and Cunia (1962) showed this almost twenty years ago. If only static information is required, nothing has to be added to this statement.

For dynamic information, however, the estimators for characteristics of change have minimum sampling error if all plots are remeasured. The optimal solution is dependent on the coefficient ρ of the correlation between the sample plot data of two successive occasions and the quotient Q of the costs of a permanent plot and a temporary plot. Sampling with temporary plots is preferable if permanent plots cost more than $\frac{1}{1-\rho}$ times as much as temporary plots (fig. 1), in all other cases sampling with permanent plots is optimal. Sampling with partial replacement is in no case to be preferred for estimating changes. For the determination of Q the costs for permanent and temporary sampling units should be estimated for exactly the same situations and the same kind of acurateness of measurements. One should of course not compare the cost of permanent plots for

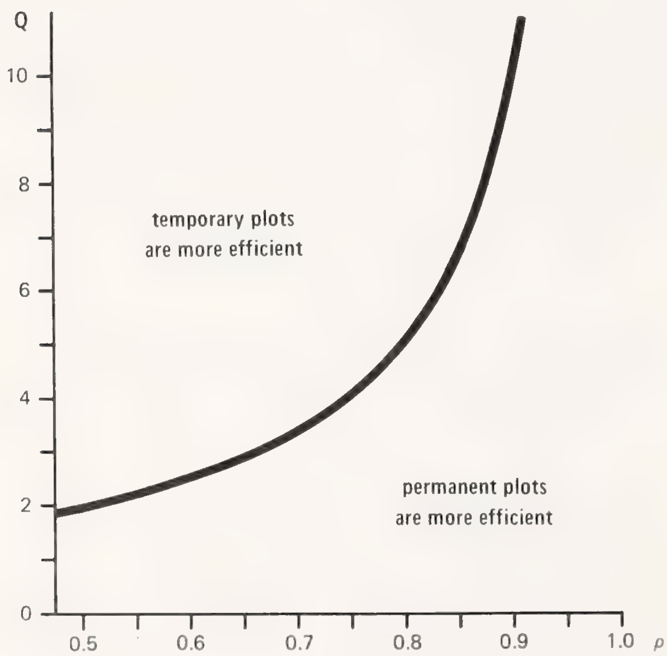

Figure 1. It shows for which combinations of the coefficient ρ of correlation between successive inventories and the quotient Q (cost per permanent plot divided by cost per temporary plot) it is preferable to apply temporary plots or permanent plots, respectively, for estimating change.

growth and yield research with those of temporary sample units for a practical inventory. The only difference in the calculated cost per unit must be due to the fact that the permanent samples should be found again. It must be taken into account that the additional costs of the remeasurement at successive occasions are lower than the additional costs for the establishment of permanent samples. Since a permanent plot will in general not cost much more than twice as much as a temporary plot and the correlation coefficient is practically always larger than 0.5, sampling with permanent plots is as a rule more efficient than sampling with temporary plots. An example may show that it is worthwhile to make the right decision: For a correlation coefficient of 0.9 and a cost relation of 2 to 1 the overall costs of a ground survey with temporary plots will be 5 times as high as a ground survey with permanent plots that leads to the same accuracy for all estimates of change.

In addition to this advantage for the estimation of net changes permanent plots will give good estimates of growth and exploitation. Growth of trees can be estimated with temporary plots only by increment borings and often these cost even more than the difference between permanent and temporary plots. The amount of exploitations that have taken place can practically only be estimated by permanent plots.

Inventories that give useful estimates of changes will in general give current means that are more accurate than necessary. If different information requirements have to be fulfilled, the requirements on dynamic variables are in general more restrictive and therefore decisive for the choice of the inventory method.

Why then are inventories without temporary plots so rare and why do so many sampling projects without any permanent plots still exist?

The main reason is probably that in general we do not look far enough ahead. The establishment of permanent plots will in general consume more time than the remeasurements of these plots. On the other hand the first inventory will not provide us any information on changes yet. Therefore, the costs at the beginning of the project are higher than later and the additional information is nil. Since one has often more than enough problems to finance the first inventory one does not think too hard of what the second inventory will bring and is content with the layout of temporary plots. Next time it will again be a first inventory. Optimization for the next inventory alone will always lead to sampling with temporary plots. The establishment of permanent samples is an investment, but it is an investment with very high benefits.

Another reason for sampling with partial replacement or without any permanent plots is the fear that some day the permanent plots might not be representative anymore. It is in fact

possible that visibly marked plots might be treated in a slightly different way from the rest of the area and we can never be sure that this will not happen. It has been suggested that one could check this at each inventory by comparing the means of the permanent sample with those of a temporary sample. This comparison is not very accurate and deviations will be recognized only when they are quite large already. Up to this time important decisions were probably based on wrong information because the plots were marked. Consequently, there is only one solution to this problem: the plots must not be visibly marked. Even the so-called "unconspicuous" marks might influence exploitation.

Other planners are afraid that the permanent plots might not be found later on. In Switzerland and Austria we have experience with not visibly marked permanent plots since 1961. Thousands of plots have been remeasured till now; all plots except one were found again. Some of them are situated in very rough alpine country sides with slopes of more than 100 % and where sometimes rock-climbing is necessary. If a few plots should not be found, it will not be a grave problem for the evaluation and interpretation of the data.

From a landmark identifiable on the ground and on the map or on the aerial photograph the center of a plot is located by using compass and tape. Once the center is defined we may measure distance and azimuth to one or even two points (rocks, trees, etc) that will be marked by red lead. These marked points must be located far enough outside the plot. To establish the permanent plot the polar coordinates of all the sample trees with respect to the center of the plot are measured and recorded. Furthermore, the center is marked by a piece of tube buried in the ground.

At the following inventory the recorded distances and directions will lead the crew from the landmark to the marked points and from there to the permanent plot. The measurements hve to be accurate enough to make sure that the crew arrive somewhere in the sample plot. To find the exact position of the center the crew consult the form for this plot, preprinted with the results of the last inventory by the computer (azimuth and distance from the center, species, diameter at breast height of all the trees, fig. 2). The surrounding trees are compared with the recorded trees on the sample plot form. In general it will be very easy to identify one of the trees on this form. Once the position of one tree is known, the center of the plot can be located exactly by azimuth and distance from this tree. Only in very rare cases it is necessary to look for the buried pipe with a metal detector. At the locations of the recorded trees there are stems or stumps, therefore, the growth of each tree can be assessed although they are not numbered. Number and kind of the cut trees give good estimates on exploitation (Schmid-Haas, Werner, Baumann, 1978).

Our experience shows:
If an inventory should give information on the development of land resources as well as on current means it is by far more efficient to establish not visibly marked permanent plots than to use temporary plots. For forest areas there are often good reasons to do without any temporary plots. Similar conclusions may be reached for inventories of arid lands with perennial and individually recognizable plants.

SURVEY WITH AERIAL PHOTOGRAPHS OR FIELD CREWS

Ground samples give sound and easily interpretable results. In general one can measure exactly what is of interest and neglect everything else. The working procedure is relatively easy to be learned. The assistance of specialists is necessary only for a small part of the work. However, field-work is very timeconsuming. It depends on the weather conditions and is partly bound to certain seasons. Time consumption and travelling costs increase the expenditure of these sampling projects in a high degree. Additional interpretations and measurements on aerial photographs can lead to a considerable reduction of standard errors of the estimations or to substancial re-

GRINDELWALD 1967 / 77 OWNER 02010 PLOT 931

CREW DATE TIME STAND TYPE OLD 615 NEW. 615 .
Balle 20/9 8.45 PLOT SIZE 400 M2 RADIUS 1139 CM

TOP HEIGHT: .19 .M SPECIES .10. STUMP:SPECIES. .AGE. .D. .CM

AZI	DIS	SP	DBH		D7M		H		RESERVE
19	97	10	25	27					
37	40	10	26	30	22	24	17	18	
41	39	10	18	20	12	15	13	15	
71	73	10	34	36					
120	77	10	33	35					
122	108	10	19	0					
122	111	10	20	21					
178	92	10	24	27					
213	34	10	18	20					
250	101	04	27	32					
314	112	10	44	47					
332	9	10	~~34~~ 29	32					
350	85	10	30	32					
225	76	10		9					
388	93	10		10					
AZI	DIS	SP	DBH		D7M		H		RESERVE

E D P - E A F V

Figure 2. Sample plot form for a successive inventory with the results of the former inventory preprinted by computer.

ductions in the necessary number of the ground plots. According to our experience a good stratification of the area by photo interpretation reduces the number of ground plots regularly by a factor of two or three (P. Schmid-Haas, 1976). Such a stratification (by stand maps or samples on aerial photographs) not only reduces the variance, but gives also estimates of the different strata in addition to the estimates of the total area.

Sampling on aerial photographs and other means of remote sensing is much cheaper than ground surveys. It is faster and does not depend on weather conditions or season. Although not everything can be seen on the photographs there are indications in most respects or often there are at least observable variables that are highly correlated with the desired values. However, in most cases, the resulting data are not gauged and therefore, must be checked on the ground. These ground checks are very often not planned and executed systematically. Many times the calibration is based on measurements taken in a small part of the area or even outside the region. Sometimes the ground measurements are taken only to instruct the photo-interpreters. In this case these measurements are very frequent in the parts that are sampled in the beginning and rare towards the end of the inventory. With the exception of a training phase it will be preferable to choose, according to plan, a small part of the photo point for systematic ground measurements. The probability for a plot to be included into the ground sample may depend on the results of the photo evaluation and on a code set by the interpreter according to the difficulties he faces in interpreting the aerial photograph at this plot. The results of the ground plots will serve for the calibration of the photo point results. In addition it is possible to collect data on the ground that are not visible on the photograph, and also to get regression estimates of these data for all the photo points. The survey is then a real combination of photo and ground sampling.

A combined inventory with photo plots and ground plots will mostly be preferable to sampling either on the ground or on photos only. Often one or the other of the sampling methods is omitted only due to the competent specialist not being at hand.

TEMPORARY OR PERMANENT PHOTO SAMPLES?

For sampling on aerial photographs, the same statistical considerations are applicable as for ground sampling. For the estimation of static data permanent and temporary samples are suitable, while for the estimation of change the permanent samples are providing the best results. Also for combined sampling on photographs and on the ground practically the same considerations are valid, as the ground sampling results may be regarded as calibration values.

The problem of finding the former sample on new aerial photographs was proved to be solvable. The general procedure is approximately as follows: The sample points are determined on maps. Therewith it can be ensured that the samples are representative for the whole area. The points must then be transferred to the aerial photographs by a projective transformation (Kölbl, 1980). For this purpose the orientation elements of the photographs and the coordinates and elevation of every plot center are needed. These point transfers can be calculated by a computer and the points plotted on a film by an automatic tracing table. At the same time the local scale for the main directions at the sample points can be calculated if aspect and inclination are known (fig.3).

At the next inventory the same procedure is repeated with the new aerial photographs. The plot centers will be near the old centers. To distinguish actual changes from differences due to displacements of the centers it is important that the interpreter has a computer output with the old photo interpretation and measurement results at hand, so that he can write the new results beside the old ones. If the instrument allows to register automatically it is useful to have the main results of the last inventory printed on the film near the plot centers. The interpreter can therewith easily detect differences due to displacements of the point and is therefore able to correct the plot center before he determines the new results. For most purposes

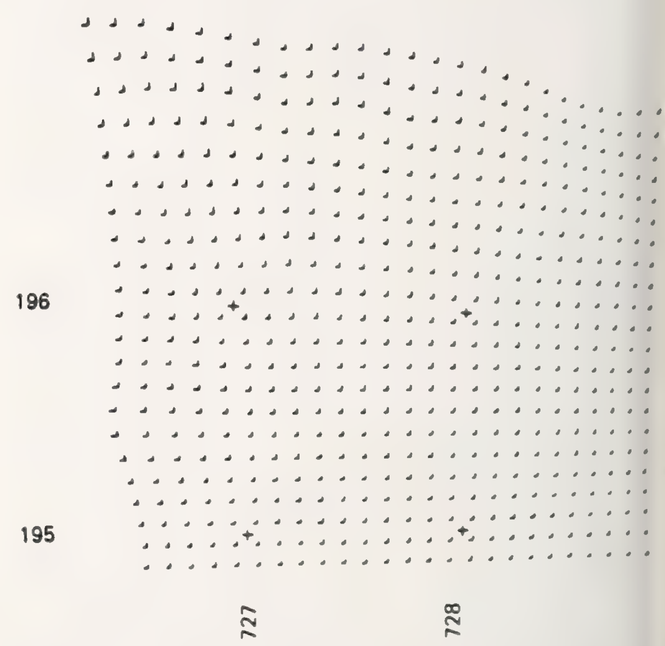

Figure 3. The systematic net of sample points is distorted and printed on a film to be adapted to the aerial photograph. The lengths of the sides of the angles may be printed so as to give the local scales in the main directions.

it will be sufficient to register whether important changes have taken place and to give the new measurements and interpretations only in the case of major changes. Measurements and interpretations on aerial photographs are in general not accurate enough to determine growth or other small changes.

It is interesting to note that the idea to have permanent sample plots on aerial photographs is quite new. However, the consequent pursuance of the purpose to survey the changes in te vegetation cover by aerial photography may call for the adoption of this system in the future (Schmid-Haas and Wullschleger, 1978).

GENERAL PROCEDURE FOR COMBINED PERMANENT SAMPLING

The above considerations lead to the following general procedure:

- A relatively dense net of sampling points is determined on the map. For each sampling point the height above sea-level and possibly slope and aspect is read from the map, distances from the next road and other useful information may also be available.

- The orientation elements of the aerial photographs are determined by measuring the location of landmarks on the map and on the photographs. The location of each sample point on the photographs is calculated and automatically printed on film by a computer. At the same time the local scales may be printed on these films. The films are fixed on the aerial photographs. Interpretations and measurements depending on the information requirements are executed for each point on the aerial photographs.

- The results of the photo evaluation may determine the probability of each plot to be included in the ground sample. The ground plots are specified by randomization.

- The field crew locate the ground plots with the help of the map and the photograph and the necessary measurements including the polar coordinates of each tree. No visible marks are left in the plots.
- The data are evaluated either by calculating regression estimates or by using the results of the photo evaluation for stratification.

For the next inventory it has to be decided whether the sample should be enlarged or only a part of the sample plots should be remeasured. At the same time new measurements and interpretations may be necessary.

- The orientation elements of the new aerial photographs are determined. The location of each sample point on the new photograph is calculated and printed on film. The computer may at the same time print the local scales and the major results of the preceding photo evaluation beside each sample point.

- The films are fixed on the photographs. The photo interpreter compares the content of the photograph at each sample point with the former results and registers major changes as far as they are not explained by displacements of the sample points.

- Sample plot forms with the recorded results of the former inventory are prepared by computer.

- The field crew remeasures the permanent plots on the ground. A substantial practical difficulty arises where major changes have occured since the aerial photograph was taken. Additional temporary ground plots may be useful where the photo evaluation shows major changes. The field crew can check the kind of change that has occured.

- Differences between the results of two successive inventories determine changes for each permanent plot. The data processing procedure may then be almost identical for change variables as for static variables. Only when estimates are based on temporary as well as permanent plots the calculations will be somewhat more involved.

In conclusion we may state that the general problems of a combined inventory with permanent sample units on aerial photographs (or other media of remote sensing) and on the ground are solved and that this is a relatively efficient method to assess change.

However, practical large area inventories for monitoring the dynamic behavior of our ecosystems under the action of man do largely not exist as yet. In view of the enormous, ever increasing, and often uncontrolled influence of man on the vegetation cover of the earth much more practical and theoretical research is necessary and urgent.

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RESUMEN

Los inventarios combinados del suelo y fotografías aéreas (u otro método de detección remoto) pueden ser de gran eficacia. Para la evaluación de cambios, los sitios de muestreo deben ser permanentes. Esto no sólo se aplica a las muestras del suelo, sino a las muestras fotográficas. Hay disponibles métodos para establecer sitios permanentes en fotografías aéreas, y sitios permanentes en el suelo sin que se utilicen marcas visibles.

En vista de la enorme influencia del hombre, en aumento y a menudo sin control, sobre la cubierta vegetativa de la tierra, el autor siente una gran preocupación ya que apenas existen inventarios prácticos para la supervisión del comportamiento dinámico de nuestro ecosistema, y la investigación para resolver estos problemas es muy lenta.

Walk-Through Inventory: A Short-cut Substitute for Remeasuring Slow-Growing Inventory Plots[1]

Colin D. MacLean[2]

Abstract.--Remeasurement of timber inventory plots is costly. An alternative would be to visit all plots to record cut, mortality, and ingrowth. The diameters, however, would be estimated by projecting the original measurements based on a subsample of remeasured plots. A test based on remeasured plot data from eastern Oregon produced reliable estimates at a substantial savings in cost.

INTRODUCTION

In the United States, the USDA Forest Service is required to make periodic assessments of the Nation's forest resources. As part of this effort, the staff of the Renewable Resources Evaluation Work Unit (formerly known as Forest Survey) of the Pacific Northwest Forest and Range Experiment Station has been making timber inventories since the early 1930's. These periodic inventories cover all private, State, county, and municipal forest land in the States of Washington, Oregon, and California. Although we employ a double-sampling design, our principal data source in most areas is a systematic grid of permanent ground plots with an average spacing of about 5.5 kilometers (3.4 mi).

Our traditional approach to reinventory has been a complete remeasurement of every field plot at intervals of about 10 years. During a recent reinventory of the relatively arid pine forest lands of central Oregon, I was struck by the slow growth rates of individual trees. Many stands had changed very little during the 13 years between measurements. Although some had changed drastically, the change was largely caused by logging and mortality. These observations led me to question the need for complete remeasurement of all plots.

Real changes in timber inventory statistics occur because: (1) Trees are cut or they die, (2) surviving trees grow, (3) new trees grow large enough to tally, or (4) trees become rotten. When we remeasure permanent plots, we learn which trees are dead or cut, how much the remaining trees have grown, and whether or not new trees (ingrowth) have become established. Cull increment is usually estimated from special studies. Although cut, mortality, and ingrowth can be identified by simple observation, the calculation of growth on surviving trees is usually based on careful remeasurement. Thus, in central Oregon, tree growth--the least important element of change--proved to be the most expensive to collect.

How could tree measurement costs be reduced without important losses in precision? One way would be to limit tree growth measurements to a fraction of the plots. The remaining plots would be visited, but observations would be limited to identification--from the previous plot record--of trees that had died or been cut, and to a tally of ingrowth. Tree diameters on these later plots would be estimated by projecting the original measurements using diameter growth equations developed from the remeasured sample. If losses in precision were not too great, the savings in cost from such an inventory might be considerable since the "walk-through" plots could be visited by one person instead of the two-person crew needed for remeasurement.

THE STUDY

Early in 1979, we began planning for a timber inventory of eastern Washington. The area was last inventoried in 1967, at which time a 5.5-kilometer square grid of permanent plots was established. Although our first plan was for complete remeasurement, we were concerned about increasing field costs and a prospectively tight

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[1]Paper presented at the Arid Land Resource Inventories Workshop (La Paz, Mexico, November 30-December 6, 1980).

[2]Colin D. MacLean is principal mensurationist, Renewable Resources Evaluation Work Unit, USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

budget. As an alternative, "walk-through" plots were proposed. The plan was to measure one-third of the plots completely using a standard two-person crew. The remaining two-thirds of the plots would each be visited by one crew member who would update the old tally by identifying trees that died or had been cut and by recording all the required classification data. No tree diameter or tree height measurements would be taken, however. These would be estimated later using the remeasured portion of the sample to relate diameter breast height (d.b.h.) taken at the previous inventory and other tree characteristics to current d.b.h. and height.

Before adopting the walk-through procedure, we wanted assurance that the results would be reasonably reliable. We were not particularly concerned about estimating tree height since height estimation from a subsample is the conventional inventory practice. We were, however, anxious for assurance that our proposed procedure for estimating diameter would produce reasonably unbiased, accurate estimates of volume and growth. Fortunately, remeasurement data from a 1977 inventory of central Oregon were available for a test. Using these data, I simulated two 1977 inventories of timber volume and growth, one based on complete remeasurement data and the other based on diameters projected by multiple regression from 1964 measurements of the same trees. The regressions for these projections were developed from a sample of one-third of the remeasured data. The results of that test are reported in this paper.

THE DATA

Each of 239 inventory plots available for the test were a cluster of three sample points spaced approximately 21 meters (70 ft) apart. At each point, seedlings and saplings were tallied on a small fixed-radius plot, poles and sawtimber trees up to 89-centimeters (35 in.) d.b.h. were tallied with a prism, and trees over 89 centimeters were tallied on a large fixed-radius plot. Two plot sizes were used, depending on plant community. In the most arid and sparsely stocked communities, a metric 4.6-factor (English 20-factor) prism sample was combined with 3.0-meter (9.7-ft) and 20.7-meter (69-ft) radius circular plots. On other areas, the prism factor was 6.9 (English 30-factor) and the plot radii were 2.4 meters (7.9 ft) and 16.9 meters (56.5 ft).

The species and d.b.h. of each tally tree was recorded both for 1977 and for 1964. Tally tree selection was based on the 1977 diameter. The total height of each tree in 1977 was also recorded and the 1964 height estimated based on site index curves. A variety of tree and plot variables were recorded including plant community, site index, slope, aspect, and the age, crown ratio, and crown class of each tally tree.

DEVELOPING DIAMETER PREDICTION EQUATIONS

The first step was to develop equations which would predict the 1977 d.b.h. from the 1964 d.b.h. and other tree and plot variables. One-third of the sample points were used for this purpose. Separate multiple regression analyses were undertaken for each of four species and one species group. Independent variables tested included crown ratio, reciprocal of tree age, the 1964 d.b.h. to various powers, the ratio of the tree diameter to the quadratic mean diameter of the stand, site index, elevation, and various cross products. The equation for Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) is given below as an example of the final equations.

$$D_n = D_o + 1.91263 + 5.613573\ CR/A - 200.428586/A + 0.0000534714(SI)(CR)(D_o^{.8}) - 0.00093192\ D_o^2,$$

where: D_n = 1977 d.b.h. in centimeters,
D_o = 1964 d.b.h. in centimeters,
CR = crown ratio in percent,
A = tree age in years,
SI = site index in meters (reference 100 years total age).

Since only one-third of the sample point data was used to develop the diameter prediction equations, approximately two-thirds of the tree data were available for an independent test of the equations. Using the equations, 1977 diameters were predicted for each of the test trees and the results compared with the 1977 measurement data for those trees. The results follow:

Species	Bias		$\sqrt{\frac{\Sigma (\text{error})^2}{n}}$	
	cm	(in.)	cm	(in.)
Lodgepole pine (Pinus contorta Dougl. ex Loud.)	0.2	(0.08)	±1.8	(0.70)
Incense-cedar (Libocedrus decurrens Torr.)	0.5	(.18)	±2.0	(.78)
Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco)	-0.3	(-.11)	±3.2	(1.24)
Ponderosa pine (P. ponderosa Dougl. ex Loud.)	0.3	(.12)	±2.2	(0.87)
Miscellaneous conifers (includes several true firs (Abies sp.) and Engelmann spruce (Picea engelmannii Parry ex Engelm.))	-0.03	(-.01)	±2.3	(0.91)

The results of this test are presented graphically in figures 1 through 5.

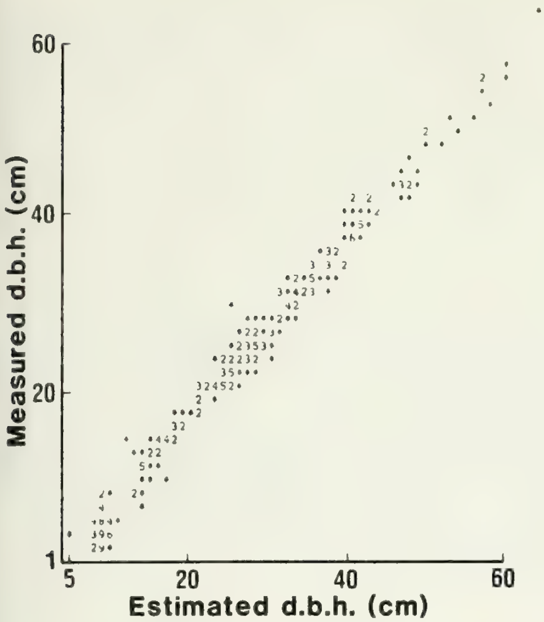

Figure 1.--The relationship between estimated and measured d.b.h. of lodgepole pine trees.

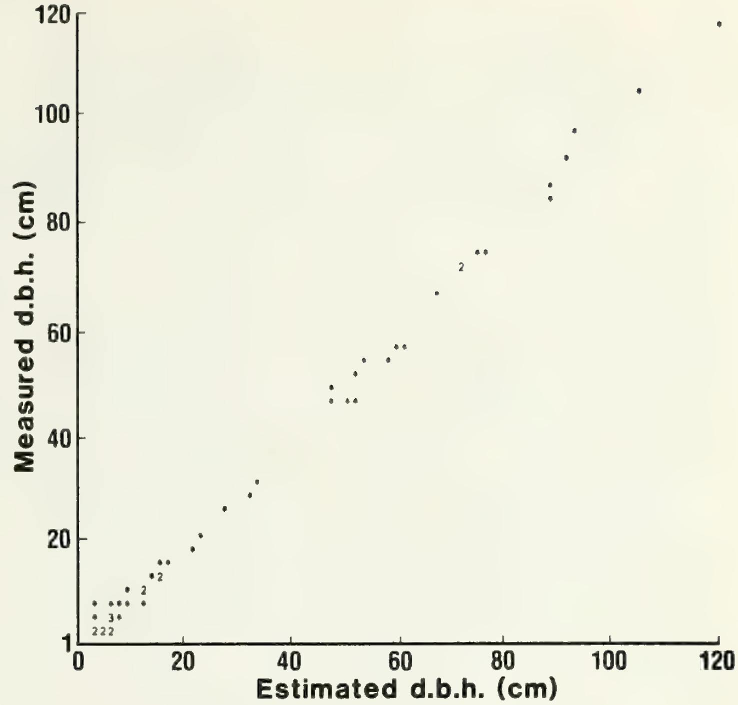

Figure 2.--The relationship between estimated and measured d.b.h. of incense-cedar trees.

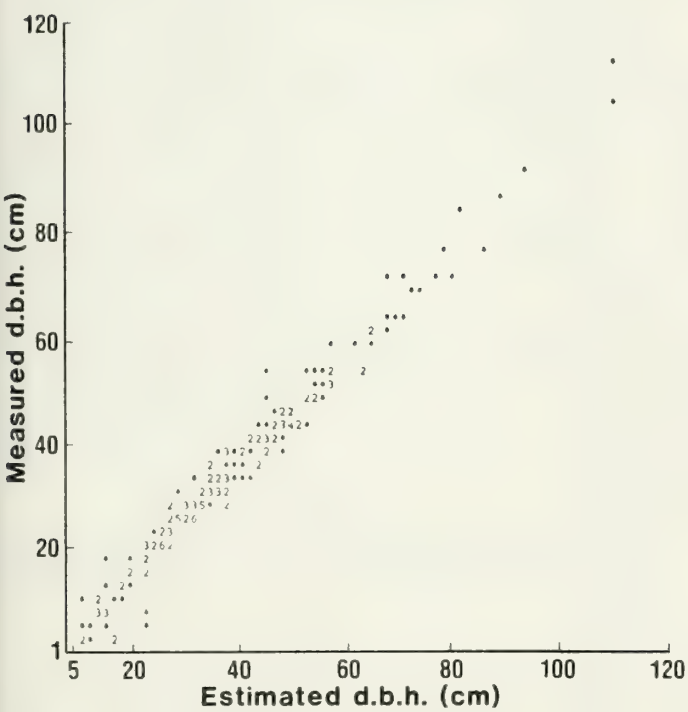

Figure 3.--The relationship between estimated and measured d.b.h. of Douglas-fir trees.

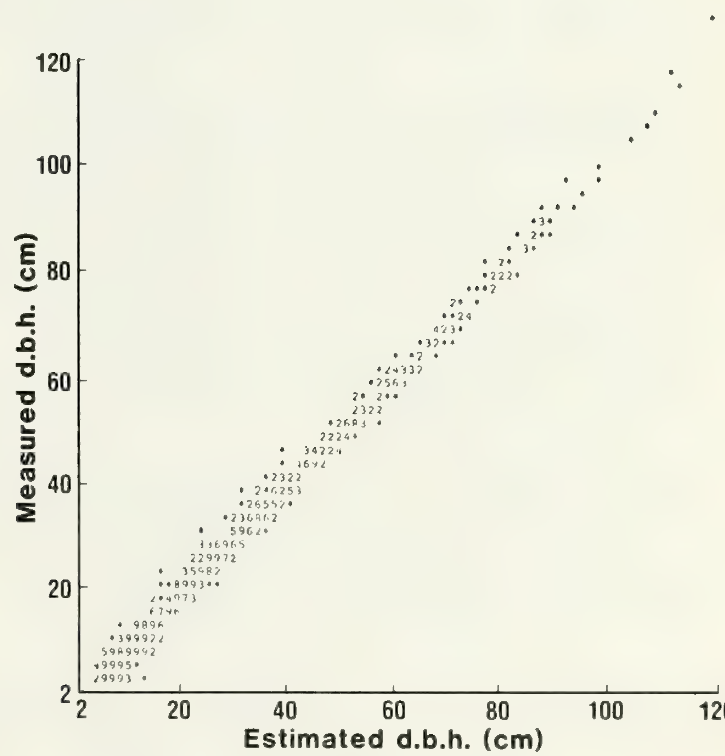

Figure 4.--The relationship between estimated and measured d.b.h. of ponderosa pine trees.

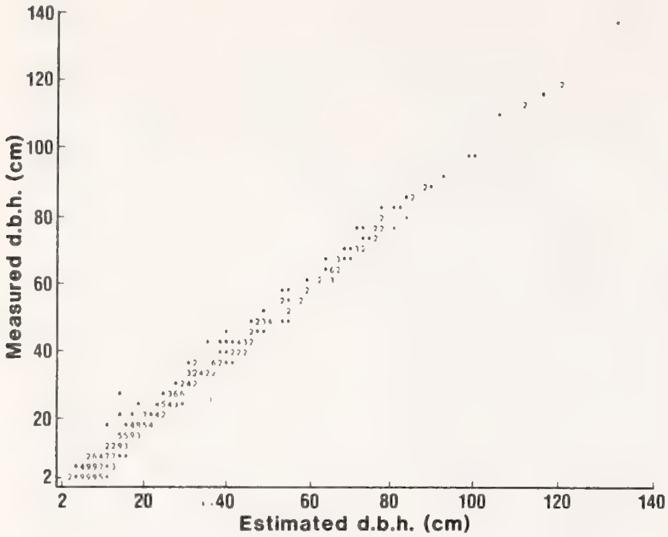

Figure 5.--The relationship between estimated and measured d.b.h. of true firs and Engelmann spruce trees.

COMPARING TWO PARALLEL INVENTORIES

The next step in our study was to use the 239 three-point plots as a base for compiling two separate inventories--identical in all respects except that one was based on remeasured diameters and the other was based on diameters that had been projected from 1964 to 1977 using the diameter prediction equations described earlier. The results of this comparison are shown in Table 1.

The volume fit was very good, with a bias of only 0.7 percent. The low root mean squared error

$$\sqrt{\frac{\Sigma\,(\text{error})^2}{n}}$$

suggests that the plot-by-plot fit is also good, a fact confirmed by the visual comparison of the plot volumes in figure 6. The

TABLE 1

	1977 remeasurement data	1977 data except d.b.h. projected from 1964 measurement
Mean volume/ha	112.8 m^3 (1,612 ft^3/acre)	113.6 m^3 (1,624 ft^3/acre)
$\sqrt{\frac{\Sigma\,(\text{error})^2}{n}}$	--	$\pm 13\ m^3$/ha (186.6 ft^3/acre)
Mean net annual growth	2.27 m^3/ha per yr (32.4 ft^3/acre per yr)	2.25 m^3/ha per yr (32.2 ft^3/acre per yr)
$\sqrt{\frac{\Sigma\,(\text{error})^2}{n}}$	--	$\pm$ 0.73 m^3/ha per yr (10.4 ft^3/acre per yr)

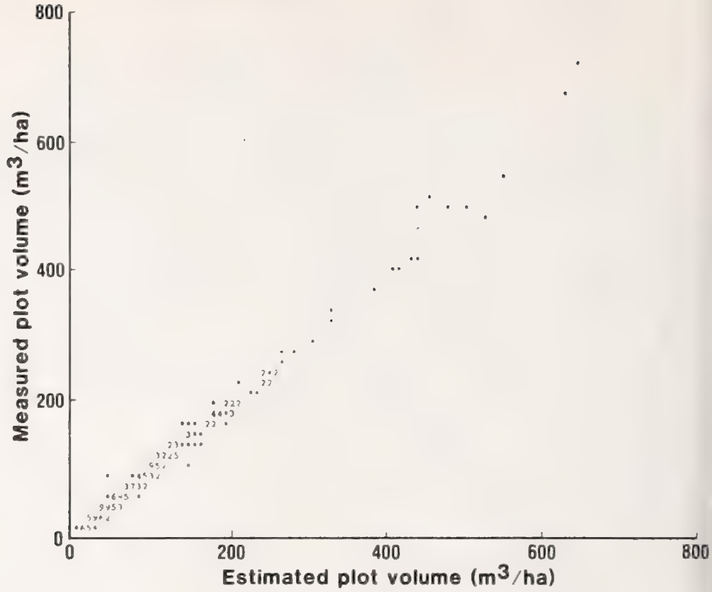

Figure 6.--The relationship of remeasured plot volumes to plot volumes based on projected d.b.h.

single greatest error was a 509-cubic meters per hectare plot that was underestimated by 65-cubic meters per hectare. Most estimates were obviously much closer.

Growth estimation was not quite as reliable. Although the bias in mean growth was negligible, individual plot estimates varied considerably--some as much as 100 percent (fig. 7). If precise growth measurements on individual plots are important, all trees should probably be remeasured on each occasion.

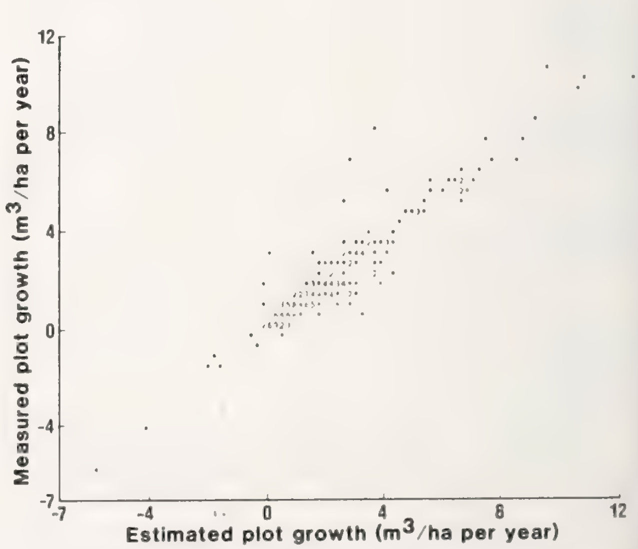

Figure 7.--The relationship of measured plot growth to plot growth estimates based on projected d.b.h.

COST

We have now almost completed fieldwork in eastern Washington. Thus far, walk-through plots have required only one-third the employee-hours per plot needed for complete remeasurement. As a result, total inventory field costs have been cut by over 40 percent. We believe that the precision achieved in the central Oregon test is adequate to meet our needs.

FUTURE REMEASUREMENT

What will we measure at the next reinventory? Although that question will not be answered for another 10 years, I see no reason why the "walk-through" approach could not be used again but with a different subset of plots remeasured. If we used a one-third sample again, we would be remeasuring 20-year-old plots and projecting some 10-year-old plots and some 20-year-old plots. We could then anticipate remeasuring 30-year-old plots 20 years hence. Maybe this is too long a period, but perhaps it won't matter by then. Changing technology and redefinition of inventory objectives may well make all the plots obsolete in another 20 years. If not, we may have to add some new plots.

A final question should be answered. "What about ongrowth trees (i.e., new trees picked up with the prism)?" Our eastern Washington inventory will be compiled from the same tree lists identified in 1967, adding ingrowth into the 2-centimeter class. We did, however, take a new prism tally at each remeasured plot location. All ongrowth trees thus identified were then measured and tagged. Those trees will not be a part of the current inventory, but they will be part of a new base for the next remeasurement. On walk-through plots, ongrowth trees were not identified.

SUMARIO

En los Estados Undios, El USDA Servicio Forestal hacen pedioricamente un asesoramiento de los recursos Forestales de la Nación. En muchas áreas, el prinicpal recursos para los datos del asesoramiento de madera es una sistematica red permanente de pedazos de terrenos.

Nuestra tradicional acercamiento para reinventario se a completado para remedir los pedazos de terrenos en aproximadamente diez años de intervalo. En ese tiempo, nosotros identificamos árboles que han estado cortados, árboles que han estado muertos (mortalidad), y nuevos árboles (en crecimiento). En Regiónes áridas, el crecimiento individual de árboles es frecuentemente despacio, con mucho cambio causado por el corte de árboles o mortalidad. Aunque corto, en crecimiento, y mortalidad pudieran identificar en los pedazos permanente de terrenos por observacion, árbol individual en crecimiento pueden solamente ser determinar por una medida cuidadosa. Asi en áreas áridas, el menos importante elemento de cambio--crecimiento del árbol--es el mas caro para colectar.

Recientas nosotros considiremos una alternativa para completar remedida en donde un terser de los pedazos de terrernos pudieran completar, usando dos persona del grupo, y el resto dos terseros pudieran ser visitados por una persona del grupo quien pudiera marcar fechas para identificar mortalidad, corto, y en crecimiento. En cresimiento en sobrevivientes árboles pudieran ser estimados despues, usando regreciones desarrollado desde la remedida de un terser de los pedazos de terrenos.

Yo probe este procedimiento, usando remedimiento datos de 239 pedazos de terrenos en Central Oregon. Primero, diametro proyectado equaciones fueron desarrollado, usando un terser de los datos. Despues dos inventarios fueron recopilado--indentico en todos respetos exepto que uno era basado en remedidos diametros y el otro en diametros que habian sido proyectado desde 1964 a 1977 usando equaciones pronosticando el diametro. El significado del volumen de pedazos remedidos de terrenos eran 112.8 metros cubicos por hectarea. El significado del volumen del inventorio proyectado eran 113.6 metros cubicos por hectarea con un error de una raiz cuadrada de 13 metros cubicos por hectarea. Segnifica un crecimiento neto anual estimado fueron casi identicos--2.3 metros cubicos por hectarea por año--con error de una raiz cuadrada, para una base estimada en diametros poryectado de 0.7 metros cubicos por hectarea por año. Recientamente en labores de prebas el costo de trabajo de labores fueron reducidos por mas de un 40 por ciento.

Equal Value Stratification for Resource Sampling[1]

Ronald M. Dippold[2]

Abstract.--A sampling procedure is described where the universe is broken up into samples of equal volume or value, as opposed to equal area. In two quite different examples in Alaska, equal volume stratification proved to be efficient in terms of time and cost required.

INTRODUCTION

Equal value or volume stratification (EVS) differs from procedures normally used in resource sampling in the way sample units are defined and selected. The experience of the Forest Service with EVS sampling will be described in two quite different examples of its application in Alaska. Other possible uses of EVS sampling will also be mentioned.

Most resource sampling procedures require fixed area plots. Two notable exceptions are variable plot and 3-P sampling, which are used mostly for timber cruising (Grosenbough 1952, 1965). Fixed area and variable plot sampling are often used in conjunction with stratified sampling and double or triple sampling to significantly increase their efficiency. Many users, however, find these more sophisticated sampling procedures difficult to apply and comprehend. In many ways EVS can be simpler in both respects.

Equal volume or value stratification assumes that the sampling universe can be broken up into samples of equal volume or value. It should be recognized that this is not always possible but some examples might include sampling timber volume, wildlife browse, or cattle forage.

If equal volume stratification can be accomplished with sufficient accuracy to obtain an acceptable sampling error, it is possible to concentrate ground sampling to fewer areas with greater intensity. The following two examples will show how EVS was used by the United States Forest Service in Alaska to sample timber resources in situations where other procedures would have been most difficult and costlier to apply. These descriptions will concentrate on how EVS solved a particular problem and how it was applied rather then on the mechanics of tree and log measurement.

1/Paper presented at Arid Land Resource Inventories Workshop (La Paz, Mexico, November 30-December 6, 1980)

2/Ronald M. Dippold is Special Assistant to Director of Timber Management, U.S. Department of Agriculture, Forest Service, Region 10, Juneau, Alaska

EXAMPLE NO. 1

PERENOSA EVS TIMBER CRUISE

The Perenosa timber sale area is located on Afognak Island, just north of Kodiak Island in the western Gulf of Alaska. From an administrative standpoint it is one of the most isolated tracts in coastal Alaska. Because of this manpower, logistics, and general knowledge considerations were important in determining cruise procedures.

These included:

1. The sale area was spread over 120,000 acres (48,560 hectares). There were 121 cutting units within the sale area averaging 94 acres (38.04 hectares) per unit. The total area scheduled for clearcut logging was 11,400 acres (4,613 hectares).

2. It was estimated that the 121 cutting units contained 332 million board feet (1.7 million cubic meters) net volume.

3. There were no unit boundaries marked on the ground, but they were located on 1/15,840 scale black and white aerial photographs.

4. There were no acceptable volume tables for Sitka spruce, the only commercial species, on Afognak Island nor were there acceptable procedures for estimating defect in standing trees.

5. It was anticipated that some portions of the sale area would be selected under provisions of the Alaska Native Lands Settlement Act and revert to private ownership at some time in the future. This would require reappraisal of volumes remaining in Forest Service ownership.

6. There were constraints on the amount of time, money, and manpower that could be expended on a cruise of the sale area.

Cruise Procedures

Each of the 121 cutting units was divided into stands of approximately equal net volume (fig. 1). The minimum size stand desired was arbitrarily set at 10 acres (4.05 hectares). A study was made of aerial photographs of Afognak Island and of existing forest inventory plots to estimate maximum net volume that could occur on a 10-acre (4.05 hectares) stand. The maximum estimated net volume was 600,000 board feet (30,600 cubic meters) per 10 acres (4.05 hectares). The cutting units were divided into equal volume stands of approximately 600,000 board feet. Stands averaged 14.85 acres (6.0 hectares) over all units. Partial stands were not allowed within a cutting unit. The EVS's were consecutively numbered from one in each unit. Total number of EVS's in all 121 units was 768. Forty EVS's were systematically chosen with a random start. They in turn were randomly ordered for field sampling to provide an unbiased order in the event that weather, equipment failure, or other problems prevented sampling of all 40 EVS's.

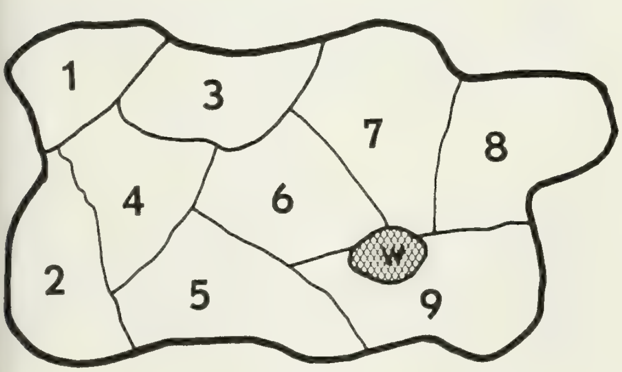

Figure 1--Sample of a cutting unit divided into equal volume stands (EVS). Water (W) not included in EVS or total area.

In the field a flag line was placed around each sample EVS and a 100 percent cruise was made of all trees using the 3-P method. About 20 measurement trees were selected in each EVS, 10 of which were felled, bucked, and scaled (Johnson 1972). The remaining 10 trees were held in reserve in the event additional fall, buck and scale trees were needed to reduce sampling error. The fall, buck and scale trees were scaled to contract specifications.

Each EVS was treated as a separate cruise at this point. All standard cruise parameters were calculated for each EVS including gross volume, net volume, log value, and logs per thousand board feet.

Net volume of each ground sampled EVS was listed and calculations were made for a simple random sample without replacement. Average EVS net volume was expanded by the total number of EVS's (768) to obtain total net volume for the 121 cutting units. Statistics would have been calculated for any variable of interest that was measured in each EVS.

Advantages:

1. It was relatively uncomplicated and could be easily explained to field men and loggers.

2. An operational ADP program was available for 3-P sampling so no development time was needed.

3. The fall, buck, and scale data provided unbiased estimates of gross and net tree volumes and provided data for volume equations for Sitka spruce.

4. Sampling error was the true sampling error. That is, there are no hidden errors, such as errors associated with volume tables.

5. As many EVS's as time, money, manpower, and weather would allow could be sampled without losing the statistical integrity of the sample.

6. "On-the-ground" lines were not required around all 121 units prior to the cruise.

Cruise Results

Thirty-five EVS's were cruised in 15 working days using a 15-man crew. Five EVS's were not cruised because of weather and a mechanical failure of a helicopter. Results of the cruise were:

Average EVS Area = 14.85 acres (6.01 hectares).

Average EVS Net Volume = 591,000 board feet (3,000 cubic meters).

Average EVS Net Volume per Area = 39,800 board feet per acre (500 cubic meters per hectare).

Total net volume on the 121 cutting units = (591,000 board feet x 768 EVS's) = 453,711,000 board feet (2,312,400 cubic meters).

Coefficient of Variation = 26.66 percent

Standard Error = 4.51 percent

Total net volume and 95 percent Confidence Limits = 453,711,000 ± 40,629,000 board feet (2,312,400 ± 207,100 cubic meters).

EXAMPLE NO. 2

VOLUME DETERMINATION FOR BEACH LOG SALVAGE

Wind and currents maintain a continuous drift of timber on to the beaches of southeast Alaska. Tightly packed wood residue is found in small pockets to strips many miles long. The Forest Service and State of Alaska wanted to develop an efficient cruising technique to determine usable wood volume on the beaches. Since the State claims all logs below mean high tide and the Forest Service all logs above mean high tide, a method was also needed to estimate the percentage of volume owned by each party. The method used had to be quick and efficient since most pieces of wood can be repositioned during a storm or an exteme high tide.

Conventional 1/15,840 scale black and white photographs were available to locate concentration areas of wood residue.

Supplementary aerial photography for sampling was obtained using a 70 MM Hasselblad 500 EL electric camera to photograph the concentration areas. The 70 MM photography was flown at two scales; 1/8,000 to be used for general orientation and 1/2,000 for cruising.

The 1/2,000 scale photographs were studied with a standard pocket stereoscope, and strips or plots of 200 logs each were counted and identified (Fig. 2). Counted logs had to be of at least merchantable size (50 board feet, .28 cubic meters). Seventy plots (EVS) were needed to cover approximately 33 miles (53 kilometers) of beach which were to be cruised. A random sample of 10 plots was selected and visited on the ground by certified Forest Service scalers who scaled all the logs on the sample plots using standard Bureau Scribner scaling procedures. As with the Perenosa equal volume cruise, each of the 10 plots was treated separately and net volume was calculated for each. Statistics were calculated as for a simple random sample without replacement and the mean net volume of the 10 samples was multiplied by the total number of 70 EVS's to obtain net volume.

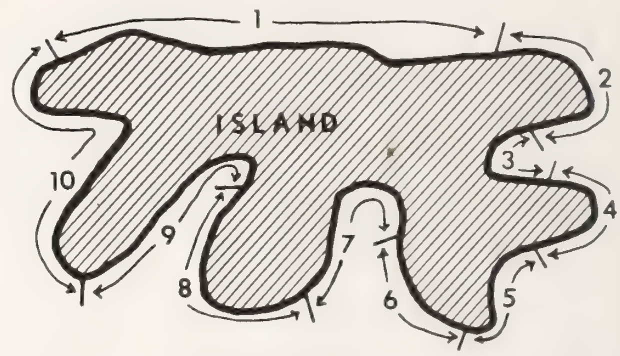

Figure 2--Sample of beach divided into equal volume units with an estimated 200 merchantable logs each.

Advantages:

1. Aerial photographs provide a record of log positions at one point in time.

2. On-the-ground measurements were limited to 10 EVS. This eliminated the need to sample logs over the entire 33 miles (53 kilometers) of beach.

3. Experienced scalers were the only people necessary for the ground work since the photo interpretation skill needed to locate the EVS boundaries was minimal.

4. Since 100 percent sample was used on the to-be-measured EVS sample, the compilation and calculations were routine and could be done with a simple desktop calculator.

5. Time required between acquisition of the aerial photographs and the final calculation was short.

Cruise Results:

Fifteen person days were needed to accomplish the cruise. The photo interpretation required one person for three days, the field work took five people two days and office calculation required two days for one person. Results of the cruise were:

Average number of measurable logs per EVS = 131.2 logs.

Average Net Volume per EVS = 8,836 board feet (45 cubic meters).

Total net volume on the 33 miles (53 kilometers) of beach = (8,836 board feet x 70 EVS's) = 618,520 board feet (3,152 cubic meters).

Coefficient of Variation = 29.70 percent

Standard Error = 9.39 percent

Total Net Volume and 95 percent confidence limits = 618,520 $\pm$ 121,660 board feet (3,152 $\pm$ 620 cubic meters)

The average number of logs (131.2) measured per EVS was considerably less than the 200 logs counted on the aerial photographs. Some older logs were ground into a flattened oval by wave and tide actions and did not meet the minimum merchantability requirement. This could be anticipated and accounted for in subsequent cruises and the standard error lessened.

OTHER USES FOR EQUAL VALUE STRATIFICATION

Spawning habitat for salmon is difficult to measure on fixed area plots because it is so variable. A Fisheries Biologist familiar with stream channel composition could mark off areas of streams on large scale photographs that would have equal spawning value. A random sample of these equal value areas could then be picked and intensively sampled on the ground. An analysis of these samples would provide a good estimate of the stream's value. A similar procedure over several randomly selected streams would provide estimates over a much larger area.

Other possible applications would be for sampling a given amount of forage for wildlife or domestic animals. This would appear to be a useful procedure when the food source covers a large area and travel is difficult and expensive.

CONCLUSION

The two examples described here suggest that EVS is an option that should be considered when designing sampling procedure. The prime consideration is the accuracy with which the EVS's can be delineated. A very experienced photo interpreter was required for the Perenosa timber cruise while the interpretation for the beach log cruise required only counting of logs.

The relative ease with which vegetation can be interpreted and counted on aerial photographs of arid land suggests that EVS may be a viable option.

The sampling technique used for the selected EVS's can also vary from the relatively complicated 3-P cruise used on the Perenosa cruise to the 100 percent resource cruise used on the beach log salvage. Of course, a 100 percent sample with the chosen EVS's greatly simplifies statistical calculations.

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RESUMEN

Se describe aquí un procedimiento de muestreo en el cual el Universo se divide en secciones de igual volumen o valor, en lugar de secciones de igual superficie. En dos ejemplos muy distintos en Alaska, se comprobó que la estratificación de volúmenes iguales es más eficiente en cuanto a costos y tiempo requeridos.

Cost Efficient Sampling Schemes — Moderator's Comments

W. E. Frayer[1]

In order to determine the efficiency of sampling designs, there must be some base against which others can be compared. We could assume either simple random sampling or, perhaps, systematic sampling for such a base. In any event, the distribution of the attribute of interest will be a determining factor affecting precision levels. Costs, particularly travel costs, will also be an important factor in determining efficiency.

Quantities of certain items, such as rare plants, can certainly not be sampled at an acceptable precision level by systematic or simple random sampling unless sampling units are huge or the number of units is excessively large. Some determination of conditions associated with the presence of such items is usually a necessary first step in designing a sampling method. Various types of stratification, ratio estimation and other methods may then be applied to develop a scheme that is relatively cost efficient--although the ultimate determination of whether the cost is acceptable must be based on the value of the information.

Arid areas are typically large, so it is to be expected that distances between sampling units are large with correspondingly high travel costs. Cluster sampling and other forms of multilevel sampling often present the means to group field observations of sampling units such that costs can be held at an acceptable level.

The papers to be presented by this panel of experts represent a few of many approaches that have been tried or proposed.

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PANEL E

Cost Efficient Methods of Estimating Ungulate Food Habitats by Fecal Analysis[1]

Allen Y. Cooperrider[2], James A. Bailey[3], and Richard M. Hansen[4]

Abstract.--Fecal analysis is one of six techniques being used to determine food habits of ungulates. Fecal analysis has several advantages over other techniques for agency personnel conducting studies or inventories on arid lands. These advantages include simplicity, minimal equipment requirements, modest cost, and budgeting flexibility.

INTRODUCTION

Food habits of wild and domestic ungulates vary among seasons, years, feeding sites, and weather conditions (Cooperrider et al. 1980). Yet land managers require information on patterns of food habits as a basis for management decisions. Land management programs in which knowledge of food habits is often necessary include:

(1) assessing damage by ungulates to forests and agricultural crops;

(2) developing habitat management plans for wild ungulates;

(3) planning for range rehabilitation projects; and

(4) allocating forage to livestock and big game utilizing common range.

Six methods for determining food habits of ungulates are currently available (Van Dyne 1968):

(1) observing free-grazing or tethered animals to note the relative abundance of different plants in their diets;

(2) estimating in plots the production and utilization of different plant species to calculate their relative use by animals;

(3) clipping plots before and after grazing to determine use by the difference;

(4) using esophageal and ruminal fistulated animals to collect samples of forage grazed, then analyzing these samples;

(5) killing animals to analyze rumen or cecum contents for botanical composition; and

(6) examining feces microscopically for botanical residues to determine dietary intake.

All these techniques have particular advantages and disadvantages with regard to precision, accuracy, repeatability, utility, flexibility, and cost. Choice of an appropriate technique will be determined by the circumstances of the study or inventory being conducted. The purpose of this paper is to describe the fecal analysis technique, describe how it has been used for an intensive food habits study of 6 ungulates on an arid-land range in southern Colorado, and discuss the advantages of fecal analysis relative to other techniques for arid-lands food habits surveys.

SAMPLING TECHNIQUE

The fecal analysis technique consists of 2 activities: field sampling and laboratory analysis. Generally, the laboratory work is done by specialists in regional fecal analysis laboratories and the resource specialist is in charge of field inventories. Laboratory procedures are well described in Sparks and Malechek (1968), Free et al. (1970), Deardon et al. (1975), and Vavra and Holechek (1980). Field sampling procedures are not as well described in the literature. Therefore, only the field procedures are described here.

Gathering fecal material in the field is a relatively inexpensive process; therefore, sampling should be designed to reflect the

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[1]Paper presented at the Arid Land Resource Inventories Workshop. [La Paz, Mexico, November 30-December 6, 1980].
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particular needs of a study or inventory in terms of animal species, time periods and localities.

Dietary studies are often designed to estimate 2 or more species food habits during different time periods. Forage residues pass the digestive tract of a large herbifore in about 24 to 36 hours (Ward 1970). Therefore, diets from short time periods such as hours or "meals" cannot be estimated by fecal analysis since there is mixing of material from different foraging periods in the digestive tract. However, fecal analysis has proven useful in estimating bimonthly, monthly, seasonal, and annual diets (Hansen and Dearden 1975; Hansen and Reid 1975; Hansen and Clark 1977; Hansen and Gold 1977; Hansen et al. 1977). However, a small number of samples from one locality should not be used to estimate diet over a much larger area since diets can be quite site specific (Ward 1970; Cooperrider et al. 1980).

A representative sample of the major species being eaten by any ungulate population can be obtained from 10 to 50 defecations per species per study area. The best procedure is to obtain a small amount from each of many defecations on several different dates during the study period. About 2 grams of material should be collected from each defecation or pellet group, or an amount equivalent to 2-3 pellets from a deer or elk. To reduce costs, these subsamples can be combined later into 1 or more composite samples. However, separate collection, identification, and labeling of samples during the field phase will allow the worker to preserve a variety of options with regard to sampling design. The final sampling design will be determined by the degree of compositing, the number of samples sent to the laboratory, and the number of slides read per sample. In some cases the field worker may wish to send some preliminary samples for analysis. These may be used to detect major sources of variation in animal diet and a sampling scheme may be designed to measure important differences among periods or locations.

When sampling only to compare areas, without regard to season, samples of any undecomposed fecal droppings may be collected. However, when seasonal data are needed, fresh droppings must be collected for each period of concern. This can be done at the middle of each month or biweekly throughout a season or year.

Field technicians must be able to recognize which droppings belong to which species of ungulate. Fecal droppings of some of the principal North American arid-land ungulates may be impossible to distinguish. Feces of cattle, horses, burros, and elk can generally be distinguished from each other and from feces of all other species whereas feces of mule deer, bighorn sheep, pronghorn antelope, domestic sheep, and domestic goats are often difficult to distinguish consistently. Thus, when 2 or more of the latter species are present on common range during the same season, the animals must be observed prior to collecting fecal samples or the fecal samples might be distinguished by some other means such as pH (Hansen 1978; Peek and Keay 1979; McCracken 1980).

Fecal samples collected in the field should be preserved to stop microbial action by freezing, air- or oven-drying, adding an equal volume of table salt, or dropping into alcohol or formalin. Preservation of samples will allow more fragments to be identified as bacteria and fungi may dissolve certain structures used to identify cellular patterns.

To identify and classify plant fragments by the microhistological technique during the laboratory phase, technicians need to become familiar with identification characteristics of the plant species present on the study area. Therefore a reference collection and a plant species list must be prepared for the area. Slides of plant reference material are used to confirm and classify plant fragments found in samples. The reference collection and species list should be a reasonably complete representation of the flora on the area since some species that comprise a small percentage of the available forage may comprise a large percentage of the diet. Reference slides can be made from freshly harvested plants, from dried plant material, or from preserved plants. Slides may also be made from whole plants or from parts such as leaves, stems, flowers and seeds. The species list and reference collection, properly labeled, should be sent to the laboratory with the fecal samples.

In summary, the field phase of a fecal analysis study consists of:

(1) collecting, identifying, and preserving fecal samples in the field for the animal species, localities, and seasons of concern;

(2) preparing a plant species list for the same localities, as well as a reference collection of the plant species; and

(3) sending samples, species list, and reference plant collection to an appropriate laboratory for analysis. Several such laboratories are now in operation in the United States and Mexico.

AN EXAMPLE - THE TRICKLE MOUNTAIN STUDY

The Trickle Mountain study illustrates the use of fecal analysis for an intensive survey of food habits of wild and domestic ungulates utilizing common range. The study was initiated in 1978 under a contract to Colorado State University from the U.S. Bureau of Land Management (BLM).

Study Area

The Trickle Mountain study area consists of approximately 80,000 hectares located in

south-central Colorado at the northern end of the San Luis Valley. The area provides year-round range for 4 species of wild ungulates, bighorn sheep (Ovis canadensis), pronghorn antelope (Antilocapra americana), mule deer (Odocoileus hemionus), and elk (Cervus canadensis). In addition, the BLM lands, which consist of approximately half the area, are grazed by cattle and horses during spring, summer and fall. These BLM lands provide critical winter range for all 4 species of wild ungulates. A major objective of the study was to determine the food habits of all wild and domestic ungulates on the area.

Methods and Materials

Ten fresh fecal samples, representing different animals were collected at 2-week intervals from the 4 wild ungulates from January 1978 through June 1979. In addition, 15 fecal samples were collected from each species of domestic ungulate for each 2-week period from each allotment whenever livestock were on the range. Because fecal samples of bighorn sheep, pronghorn antelope, and mule deer could not be consistently distinguished, animals were observed in the field prior to making collections. A total of 2715 samples (1560 from wild ungulates and 1155 from domestic livestock) were collected. These were preserved in salt and sent to the Composition Analysis Laboratory at Colorado State University for analysis, where one slide was prepared and botanical composition was determined from each sample. Because no samples were composited, results from each slide represent an estimate of the diet of one animal during the given collection period.

Results

Results of fecal analyses of wild ungulates indicates that a large portion of the year-round diet of any species is composed of less than 6 genera (table 1). Detailed analyses of bighorn sheep diets have been reported (Cooperrider et al. 1980) and data on other species will be presented elsewhere. Food habits tended to be very site specific and thus were of limited general interest. Results presented here show the degree to which plant species characterize the diets of the ungulates studied, and the precision with which the dietary composition of such major species can be estimated.

A total of 85 genera was observed in samples from wild ungulates from 1978. The technique is designed to identify plant fragments at the generic level, however, on our study area most genera included only 1 species that was present in sufficient abundance to be an important component of the diet.

Although a large number of genera were present, the 10 most common genera in any seasonal diet of an ungulate species accounts for at least 65% of the diet (table 2). Furthermore, only 2-9 genera contributed 5% or more to any seasonal diet (table 3).

The precision of the technique in estimating percentages of the major plant species (standard deviation/mean) in the diet is indicated by the coefficients of variation (table 4).

Table 1.--Year-round food habits of Trickle Mt. ungulates, 1978, as determined by fecal analysis.

Species	Dietary Composition[2,3]			
	BS	PA	MD	E
Grass and Grasslike Plants	38	3	7	43
Fescue (Festuca sp.)	7	-	1	11
Bluegrass (Poa sp.)	2	-	1	5
Muhly (Muhlenbergia sp.)	10	1	1	4
Sedge (Carex sp.)	5	1	2	8
Other Grass	14	1	2	15
Forbs	7	17	10	11
Cinquefoil (Potentilla sp.)	2	5	2	3
Other Forbs	5	12	8	8
Browse	55	80	83	45
Juniper (Juniperus sp.)	-	-	7	-
Willow (Salix sp.)	1	-	22	2
Saltbush (Atriplex sp.)	11	7	6	2
Mountainmahogany (Cercocarpus sp.)	6	5	4	1
Rabbitbrush (Chrysothamnus sp.)	1	18	5	4
Sagebrush (Artemisia sp.)	25	39	19	18
Other Browse	11	11	20	18

[1]Only plants comprising more than 5% of the year-round diet are reported.

[2]Dietary composition is expressed as percent relative density in fecal samples.

[3]Abbreviations used are: BS, bighorn sheep; PA, pronghorn antelope; MD, mule deer, E, elk.

Table 2.--Percentage of diets composed of 10 most common genera in seasonal diets of ungulates from Trickle Mountain, Colorado as determined by fecal analysis.

Season	Species[1]					
	BS	PA	MD	E	C	H
Winter	91	96	90	86	nd[2]	nd
Spring	77	78	76	74	92	96
Summer	70	86	97	72	92	95
Fall	84	92	77	67	95	98
Year-round	76	78	77	63	nd	nd

[1]Abbreviations used are: BS, bighorn sheep; PA, pronghorn antelope; MD, mule deer; E, elk; C, cattle; H, horse.

[2]nd indicates that no data are available for the season.

Table 3.--Number of genera comprising at least 5% of the seasonal diets of ungulates from Trickle Mountain, Colorado, as determined by fecal analysis.

	Species[1]					
Season	BS	PA	MD	E	C	H
Winter	4	3	5	4	nd[2]	nd
Spring	4	3	5	7	4	3
Summer	4	5	2	5	4	4
Fall	6	3	9	8	5	2
Year-round	5	4	4	3	nd	nd

[1]Abbreviations used are: BS, bighorn sheep; PA, pronghorn antelope; MD, mule deer; E, elk; C, cattle; H, horse.

[2]nd indicates that no data are available for the season.

Table 4.--Mean coefficients of variation for intermediate and major species in seasonal diets of ungulates from Trickle Mountain, Colorado, 1978, as determined by fecal analysis.[1,2,3]

	Species[4]					
Season	BS	PA	MD	E	C	H
Winter						
Major sp.	0.39	0.46	0.82	0.48	nd[5]	nd
Intermediate sp.	1.29	1.41	1.75	1.02	nd	nd
Spring						
Major sp.	0.87	0.57	0.95	1.02	0.46	0.72
Intermediate sp.	1.13	1.18	3.53	1.36	0.67	nd
Summer						
Major sp.	1.20	0.75	0.25	0.72	0.65	0.60
Intermediate sp.	1.63	1.12	1.36	1.06	0.85	1.65
Fall						
Major sp.	0.81	0.66	1.48	2.24	0.51	0.34
Intermediate sp.	1.21	1.51	3.30	1.54	0.94	nd
Year-round						
Major sp.	1.41	0.82	2.17	1.18	nd	nd
Intermediate sp.	2.02	3.64	2.75	1.21	nd	nd

[1]Intermediate species are those comprising 5 to 10% of a seasonal diet; major species are those comprising over 10%.

[2]Coefficients of variation are expressed as standard deviation/mean.

[3]Mean coefficients are calculated by averaging the coefficients for all species in the category.

[4]Abbreviations used are: BS, bighorn sheep; PA, pronghorn antelope; MD, mule deer; E, elk; C, cattle; H, horse.

[5]nd indicates no data are available for the given season and/or species class.

Cost

Although some costs associated with a study such as this are difficult to quantify, the total cost of this study using liberal estimates for person-days and for cost per person-day was under $30,000 (table 5). Costs were based upon a person-day = $100 and laboratory costs of $5 for reading 1 slide per sample. Travel costs were not included in the total cost since these vary greatly depending on the type of study and location of the study area.

Table 5. Approximate costs for Trickle Mountain food habit study utilizing fecal analysis.

Item	Cost[1]
Field Collection	
Personnel	
(91 days @ $100/day	$9,100
Supplies	200
Laboratory Analyses	
(2715 samples @ approximately $5.00/sample	13,500
Data Analysis	
Personnel	
(50 days @ $100/day)	5,000
Computer Time	1,000
Total	$28,800

[1]All costs are expressed in United States dollars.

Discussion

Management of vegetative resources is generally focused on a few key plant species in a given area even though a large number (50+) of minor plants are commonly observed in the annual diets of many ungulates. Furthermore, a relatively small number of genera may comprise a large percentage of any seasonal diet of such ungulates. When this is true, the primary purpose of food habits surveys for management purposes should be to determine dietary composition for major and intermediate plant species or genera.

Most ungulates are generalist herbivores and are quite opportunistic in their foraging behavior.

This results in great variation in levels of minor and intermediate species in the diet. Many investigators have attributed evidence of such variation to inadequacies of the technique used to estimate food habits. However, given the inherent variability of ungulate diets, obtaining precise estimates of dietary composition for minor and intermediate species may require extremely large sample sizes regardless of the technique used. For this reason, many investigators use food habit studies to determine which plant species are major, intermediate, and minor components of the diet without trying to estimate their percentages in the diet with great precision.

Variation in results of fecal analyses among pellet groups collected within seasons on the Trickle Mountain study area illustrates precision of the fecal analysis technique when used for assessing food habits. The Trickle Mountain study area is 80,000 hectares and contains 15 major vegetation types and is thus typical of many study areas that contain year-round range for wild ungulates.

A detailed analysis of variation in bighorn sheep food habits from this area indicated that food habits are very dependent upon the vegetation types being utilized (Cooperrider et al. 1980). Thus variation in food habits was greatest when animals were utilizing a diversity of types. This explains, for example, why the coefficients of variation (table 4) are relatively high for deer and elk in fall when animals are migrating and utilizing several vegetation types as opposed to winter when they are concentrated on relatively homogenous areas. Conversely coefficients for cattle and horses are based upon data from animals confined to 1 allotment with a limited vegetative diversity and are consequently lower. Thus, vegetative diversity results in local variation among food habits of ungulates, reducing precision in estimating average diets and increasing the sample size that will be needed to attain a given precision in estimating average diets.

Coefficients of variation in table 4 may be used in estimating sample sizes for food habits studies. When choosing a coefficient of variation to use to determine sample size one must consider the vegetative diversity of the study area. When animals are utilizing several quite different vegetation types, larger coefficients of variation such as reported for deer and elk in the fall may be appropriate. However, if the vegetation types are reasonably distinct and separated geographically such that animals do not utilize more than one type in a 48-hour period, then stratified sampling with smaller sample sizes may be more efficient and provide more insight into dietary selection.

Sample sizes required for a given confidence limit and precision level can be predicted using these coefficients. The formula below has been used in dietary studies (Johnson and Laycock 1962).

$$N = (t^2 \times CV^2)/P^2$$

where N = necessary sample size

t = appropriate table t value for a given confidence level (such as for 90% confidence)

CV = coefficient of variation, and

P = desired level of precision.

Two examples will illustrate how this formula may be used for major and intermediate species.

An investigator may desire to estimate the percentage of a major forage species within ±20% of its level in the diet at the 95% confidence level. Given a coefficient of variation of 0.6 and using an average t value of 2.0 for reasonably large sample sizes (20+), substituting in the formula above gives:

$$N = (2^2 \times 0.6^2)/0.2^2 = 36$$

Thus for a plant species that actually comprised 50% of a seasonal diet, the estimate of its level in the diet based on 36 samples (defecations) would fall between 40-50% (±20% of 50%) in 95 out of 100 collections of defecations.

With intermediate species the same degree of precision may not be required (and would require a larger sample size than for major species). An investigator may desire to estimate the percentage of an intermediate species within ±30% of its level in the diet at the 90% confidence level. A coefficient of variation of 1.2 would thus yield

$$N = (1.2^2 \times 1.7^2)/0.30^2 = 46$$

Thus for a plant that actually comprised 10% of a seasonal diet, the estimate of its level in the diet based on 46 samples (defecations) would fall between 7-13% (±30% of 10%) in 95 out of 100 collections.

Accuracy of the fecal analysis technique has been a subject of continuing concern (Holechek et al. 1980; Holechek and Gross 1981). This study was not designed to assess accuracy and the data collected are not adequate for such purposes. However, many hours were spent in the field observing animals feeding. Food habits obtained from fecal analysis confirmed qualitative observations of available forage and of observed feeding.

The Trickle Mountain study is one of the most intensive studies reported to date on the food habits of 4 or more wild ungulates occupying common range with 1 or more species of domestic livestock. In this perspective, the total cost was quite reasonable. Furthermore, for management purposes essentially the same data could have

been obtained at approximately one-tenth the cost by compositing seasonal samples (table 6). The estimates of variance among individual animals would have been lost. However, determination of average diets rather than estimating variation in diets among individual animals is generally the primary objective of management studies or inventories. Costs will increase in the future due to inflation and higher labor costs. The unit costs for laboratory analysis shown in table 6 reflect current rates. However, by expressing costs in terms of person-days and unit costs for samples, costs of future studies should be predictable.

Table 6. Hypothetical costs for a year-round food habit study utilizing fecal analysis of composited samples for 6 ungulate species.

Item	Cost[1]
Field Collection	
Personnel	
(12 days @ $100/day)	$1,200
Supplies[2]	100
Laboratory Analysis[3,4]	
(120 slides @ $10/slide)	1,200
Data Analysis	500
Total	$3,000

[1]All costs are expressed in United States collars.

[2]Based upon 3 days per season times 4 seasons.

[3]Based on 6 ungulate species times 4 seasons for a total of 24 composite samples; 5 slides read from each sample for a total of 120 slides.

[4]Cost per slide reflects rates as of December 1980.

Most costs incurred in a food-habit study are either directly or indirectly for labor. The only major cost for the field phase is for field technicians to observe animals and collect samples. Furthermore, the major cost incurred in the laboratory phase of the study is for trained technicians to prepare and read slides. Thus the entire technique requires a minimum expenditure for capital equipment and expendable supplies and is thus labor intensive.

Fecal collections for the Trickle Mountain project were initiated in January 1978 prior to completion of a contract to cover the cost of laboratory analyses. This illustrates a major advantage of fecal analysis: budget flexibility. On this project, money to cover the laboratory costs was obtained as expected. However, if the money allocated had been insufficient to cover such costs, fecal samples could have been saved and the project could have been completed at a later date as money became available or comparable samples could have been composited to reduce laboratory costs.

COMPARISON OF FECAL ANALYSIS WITH OTHER TECHNIQUES

Arid land ungulate populations are typically found in low densities over large areas, where travel is difficult and animals may be hard to locate. In addition, food habit studies by resource management agencies must often be conducted with quite limited manpower and money. Under these conditions, fecal analysis has been demonstrated to be a practical and efficient tool for estimating food habits.

Six methods of food habits determination were described above: (1) animal observation, (2) sample plot estimation, (3) before and after plot clipping, (4) fistulated animals, (5) rumen or cecum analysis, and (6) fecal analysis. A brief comparison of fecal analysis with these other methods in terms of practicality and cost efficiency suggests why many arid land resource agencies are increasingly utilizing fecal analysis. No attempt will be made to completely review the advantages and disadvantages of each technique, and as indicated earlier, assessment of the accuracy as opposed to precision of any technique is beyond the scope of this paper.

Animal Observation

A major disadvantage of determining food habits by observing feeding animals is that it is very time consuming, even with domestic or tame animals. When populations are found in low densities, and are difficult to locate, often more time is spent in locating animals than in observing them. Furthermore, species that are hunted are difficult to watch because they avoid humans. These difficulties can be overcome through the use of tame animals. However, raising wild ungulates in captivity so they can be used in feeding trials is generally very expensive as well as time consuming. Special facilities need be constructed and the animals require special care. The time and cost involved generally exceeds the resources available to an agency for routine studies or inventories.

Plot Estimation and Plot Clipping.

These 2 techniques have a major disadvantage in common; they cannot be used to determine food habits where more than 1 ungulate is present on the range. In addition, where animal densities are low and grazing is widely dispersed, both techniques may require very large sample sizes to adequately quantify utilization.

Fistulated Animals

Use of fistulated animals is obviously a very specialized technique requiring special equipment

and highly skilled personnel. Furthermore, most studies with fistulated animals have been performed with domestic animals and only a few species of wild ungulates have been successfully fistulated. The fistulated animal technique will continue to be quite useful for research but it is unlikely to be used by resource management agencies for routine inventories or studies.

Analysis of Rumen and Cecum Contents

The major difficulty with rumen-contents analyses is that animals must be killed. Where animals are found in low densities such killing may not only be damaging to the resource and unacceptable to the public, but time consuming and difficult as well. For example, on Trickle Mountain we would have had to sacrifice virtually the entire population of pronghorn antelope and bighorn sheep in order to obtain a sample size comparable to that obtained from fecal analysis.

Fecal Analysis

Fecal analysis can overcome many of the above difficulties. The technique is particularly well suited to arid lands since fecal droppings preserve well in arid climates and can thus be easily collected and analyzed months or even years after being deposited. The technique can be used where more than 1 animal species is present on the range. It does not require the expense and time for use of tame and/or fistulated animals nor require specialized equipment nor highly trained personnel in the field phase. Finally, it does not require killing domestic or wild ungulates.

An additional advantage that is often overlooked is that with fecal analysis the evidence is preserved on microscope slides. Microscope slides can become a permanent record to settle disputes that might even be appealed in a court of law. A technician's work can be independently checked by others for errors or discrepancies if the microscope slide specimens are saved. This is a definite advantage over techniques such as animal observation or plot sampling which do not provide objective ways to verify the records of an observer.

Considerations of cost and budget flexibility make fecal analysis quite attractive for those conducting inventories or studies for government agencies. Agency personnel must typically work with limited budgets that are often unpredictable from year-to-year or even month-to-month. Techniques requiring tame animals require stable funding at a fairly high level as animals must be constrained, sheltered, fed and cared for on a continuing basis. Fecal analysis is a more flexible approach since laboratory analyses can be postponed and/or a sampling design can be modified in mid-study to fit an amended budget.

Finally, fecal analysis is a labor intensive technique. This may be an important consideration in areas or agencies where equipment is expensive or difficult to obtain and/or where labor is inexpensive relative to capital goods.

SUMMARY

Food habits of wild and domestic ungulates vary among seasons, years, feeding sites, and weather conditions. Yet land managers require information on patterns of food habits as a basis for management decisions. Fecal analysis is one of six methods available for obtaining such information. The technique is simple to apply and requires a minimum of training or expensive equipment. Fecal analysis was used to study the year-round food habits of 6 species of wild and domestic ungulates on a semiarid range in southern Colorado. Results from this study indicate that 10 or less plant species generally comprise most of any seasonal diet. Coefficients of variation (standard deviation/mean) are presented for use in determining sample sizes for future studies. Total cost for the study was less than $30,000, however, costs for a comparable study could be reduced to approximately $3,000 by compositing samples. Compared to other available methods, fecal analysis has the advantage that it is not particularly time consuming, it can be used where more than 1 species of ungulate is present on a range, it does not require keeping tame animals or killing wild or domestic ungulates, and it does not require highly trained personnel nor expensive equipment. Costs are relatively modest and it allows for some budgeting flexibility. These characteristics make it an attractive technique for use by resource management agencies conducting studies of ungulate food habits on arid lands.

RESUMEN

Los habitos de alimentacion de animales ungulados, silvestres y domesticos varian de acuerdo a la estacion del ano, lugares de pastoreo y a las condiciones climatologicas. Actualmente los manejadores de los recursos naturales requieren informacion para apoyarse en la toma de decisiones efectuando asi un mejor manejo del recurso. El analisis fecal es un metodo disponible para la obtencion de dicha informacion ya que es simple de efectuar y no requiere un entrenamiento o equipo especial, que esto resultaria muy costoso. Este metodo fue utilizado en este estudio durante todo el ano para determinar los habitos de alimentacion de 6 especies de ungulados, silvestres y domesticos, en areas semi-aridas del sur de Colorado. Resultados de este estudio indican que no mas de 10 especies de plantas componen la dieta en cualesquier estacion del ano. Coeficientes de variacion son presentados para usarse en la determinacion del tamano del muestreo para futuros estudios. El costo total de este estudio fue menor de $30,000.00, sin embargo este podria ser reducidos $3,000.00 si se utilizan muestras comuestas para estudios consecuentes. Comparado con otros metodos disponsibles, el analisis fecal tiene

la ventaja que no se lleva mucho tiempo, puede ser utilizado donde exista mas de una especie de ungulados presentes en el pastizal, tampoco capturar o domesticar a los animales silvestres ni matar alguno de ellos, no es necesario personal altamente adiestrado o algun equipo costoso, los costos son relativamente modestos, y esto hace una mayor flexiblidad en el monto de la inversion. Estas caracteristicas hacen que la tecnica sea atractiva para su uso por las agencias manejadoras de los recursos para estudios de los habitos de alimentacion en zonas aridas.

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Ensayo de Cinco Esquemas de Muestreo Aplicados al Inventario de "Datilillo" (Yucca valida) y "Cardón" (Pachycereus pringlei).[1]

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Ricardo Oliva G.[2]

Resumen.- La urgente necesidad de incorporar la vegetación del desierto mexicano a la actividad económica, requiere de la generación y aplicación de métodos de muestreo prácticos y eficientes para inventariar las poblaciones silvestres de especies útiles. En este trabajo se comparan cinco esquemas de muestreo para dos especies distribuidas ampliamente en la Península de Baja California y se proporcionan los resultados obtenidos al analizar su eficiencia en relación al tiempo y costo de su aplicación y la precisión de la información derivada de ellos.

GENERALIDADES

La vegetación desértica de México ocupa aproximadamente el 40% de la superficie total del Territorio Nacional. Desde 1930 a la fecha, varios científicos se han dedicado a su estudio asignándole diferentes denominaciones (Ruebel 1930), (Leopold 1950), (Beard 1955), (Miranda y Hernández 1963), (Rzedowski 1966) y (Flores et al. 1971), siendo la más reciente la de "matorral xerófilo" (Rzedowski 1980). Este tipo de matorral cubre gran parte de la Península de Baja California y su presencia se extiende sobre una superficie de 62,670 Km^2 (Shreve 1964), lo que representa un 44% de su área total.

Dentro de los dos Estados que se encuentran inscritos en la Península, el matorral xerófilo integra una amplia variedad de especies que van desde el tipo arbóreo hasta el herbáceo, pasando por el arbustivo, suculento y rosetófilo cuya utilidad actual y potencial es bastante manifiesta. De un gran número de las especies anteriores, puede derivarse una serie de productos como ceras, especias, jabón, aceites, madera, forraje, saponinas, frutos y semillas. Algunos de estos productos pueden adquirir tracendencia económica en aspectos tan importantes como la alimentación humana y animal, industria químico-farmaceútica, construcción de viviendas rústicas, en cordelería y productos derivados, artesanías y producción de plantas ornamentales.

A pesar de que algunas especies constituyen actualmente una de las fuentes de ingresos para muchas familias campesinas, su aprovechamiento además de apoyarse en métodos tradicionales, no se fundamenta en estudios sólidos de índole técnica, lo cual implica un grave riesgo para la supervivencia del recurso.

Se desconocen algunos de los aspectos básicos, en muchas de las especies útiles de la Península, entre los cuales pueden mencionarse: abundancia y distribución; potencial productivo, de desarrollo, de regeneración; interrelaciones con el medio ambiente, manejo en estado silvestre, producción económica, etc. Lo anterior enmarca la necesidad de llevar a cabo estudios paralelos de evaluación e investigación que aporten la información necesaria para determinar la factibilidad de integrarlas al aprovechamiento, a través de un manejo adecuado.

INTRODUCCION

En el matorral xerófilo de la Península de Baja California se integran dos especies de utilidad actual y potencial: el datilillo (Yucca valida) y el cardón pelón (Pachycereus pringlei). El primero se encuentra distribuído prácticamente en toda la Península (Matuda y Piña 1980), en tanto que el segundo se localiza desde el paralelo 31° hasta el extremo sur de la misma (Shreve 1937, 1951).

Ambas especies han estado sometidas al apro-

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[1]Trabajo presentado en el Evento Internacional "Inventarios de Recursos de Zonas Aridas", La Paz, B.C.S., México, Nov. 30 — Dic. 6, 1980.

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vechamiento tradicional doméstico; sin embargo, los productos que pueden derivarse del datilillo permiten suponer que su aprovechamiento comercial sea prácticamente una realidad en un futuro próximo.

Entre los usos actuales y potenciales de las dos especies, se destacan los siguientes:

Datilillo

- La fibra extraída de las hojas y tallos pueden utilizarse para elaborar cordeles, bolsas, sandalias, redes, costales, hamacas y en forma local para atar las hojas de palma en los techados de las casas rústicas.
- De la raíz se obtiene una substancia que se utiliza como substituto del jabón.
- Las flores, raíz y frutos constituyen un alimento adecuado tanto para el hombre como para el ganado.
- El fuste se aprovecha para el establecimiento de cercos y contención de taludes; seco, constituye un excelente combustible.
- De las hojas, frutos y fuste puede obtenerse saponinas, cuyos derivados tienen múltiples aplicaciones en la agricultura y la industria.
- De la semilla puede extraerse aceite con posibilidades de uso industrial y consumo humano.

Cardón

- Del fruto se obtienen substancias pécticas utilizadas en la elaboración de jaleas de empleo culinario y medicinal.
- Las flores, frutos y tallos tiernos sirven como forraje en temporadas de extrema sequía.
- Los tallos secos constituyen un excelente combustible, y frescos se utilizan para la construcción de cercos.
- El fruto crudo ó seco es comestible.
- Las placas delgadas extraídas de la parte carnosa del fuste actúan como analgésico, cicatrizante y desinfectante, cuando se aplican a las heridas.

Aún cuando de estas dos especies pueden obtenerse productos que satisfacen algunas necesidades locales y cuyo aprovechamiento podría, además constituír una fuente de ingresos para muchas familias, resulta sorprendente observar que existe escasa información sobre ellas.

Al respecto, cabe mencionar que no existen estudios prácticos ni de investigación sobre inventarios de especie y producto. La falta de estudios sobre esta temática, para las especies consideradas y afines, obedece a la carencia de métodos adecuados para este propósito, al poco interés que se presta a las especies desérticas, a la multiplicidad de especies presentes y a la dificultad que implica la medición de sus variadas características.

El presente trabajo tiene como propósito hacer una contribución en relación a la aplicación de esquemas de muestreo, enfocados al inventario de las dos especies mencionadas.

ANTECEDENTES

En relación a la vegetación y especies útiles del desierto mexicano, existe una abundante literatura sobre aspectos botánicos, taxonómicos, fotoquímicos y descriptivos de las áreas en que se desarrollan; sin embargo, se ha detectado muy poca información referida a la temática de inventarios de especies y/o productos.

La información sobre inventarios de vegetación árida a que se hace referencia en el párrafo anterior, se puede resumir en lo siguiente:

- El Instituto Nacional de Investigaciones Forestales llevó a cabo un trabajo denominado "Estudio Ecológico - Dasonómico de las Zonas Aridas del Norte de México" (Marroquín, Borja y de la Cruz, 1974), en el que se integraron superficies importantes de varias entidades, derivando información sobre especies de utilidad actual y potencial a partir de sitios de forma cuadrada de tamaño variable (10X10 m, 20X20 m y 50X50 m).
- Muy recientemente la Dirección General del Inventario Forestal inició ensayos tendientes a derivar procesos metodológicos para llevar a cabo el inventario de especies y producto de vegetación desértica. El primer ensayo se efectuó en una zona de 2,000 Ha, en el Estado de Coahuila, generándose información para diferentes especies útiles (guayule, lechuguilla, candelilla y otras), dentro de sitios de forma circular de 10, 100 y 1,000 m^2. Los sitios se integraron en conglomerados equidistantes a 500 m. uno de otro.
- La Comisión Nacional de Zonas Aridas, algunas Universidades del Norte del País y varias Jefaturas de los Programas Forestales de los Estados de las regiones áridas, han efectuado inventarios de algunas especies útiles, utilizando como unidades muestrales cuadros, rectángulos y fajas, equidistantes, de tamaño variables.
- Como puede observarse por lo anterior, se han realizado algunos intentos enfocados a llevar a cabo inventarios de vegetación y especies desérticas. Sin embargo, no existe en ellos uniformidad de criterios en cuanto a las técnicas de muestreo a emplear, el tipo y precisión de los datos a generar, los parámetros a derivar y el marco general de análisis de los resultados.

PROPOSITOS DEL ESTUDIO

Objetivo

Mediante el desarrollo de este estudio se -- pretende determinar la eficiencia de cinco esquemas de muestreo aplicados al inventario de datilillo y cardón, en una zona comprendida dentro de la Región de Los Cabos.

Metas

A través de la ejecución del estudio se pretende:

— Establecer la precisión de la información derivada de los diferentes esquemas en relación a un testigo, mediante la comparación de estimadores para algunas variables.

— Derivar el tiempo y costo de aplicación de los cinco esquemas de muestreo, en función de los tiempos de levantamiento del sitio, caminamiento entre sitios, y caminamiento entre conglomerados y líneas.

— Incluír variables que permitan la continuación del estudio para llevar a cabo el inventario de productos (fibra, substancias activas, etc.), que puedan derivarse de estas especies.

— Derivar el proceso metodológico general de aplicación a las especies consideradas y especies afines.

CRITERIOS Y METODOS

Elección de las Especies

Las dos especies integradas al estudio, se seleccionaron tomando en consideración las razones siguientes: 1) existen en forma abundante, prácticamente en toda la Península; 2) el datilillo tiene importancia actual, en tanto que el cardón ofrece un potencial poco explorado; 3) no -- existen estudios sobre inventarios de especie y producto para ambas especies; 4) se requiere de la derivación de métodos de inventarios para determinar el potencial productivo y su incorporación a la actividad económica, y 5) que la información derivada del estudio será de importancia únicamente para determinar la eficiencia de los esquemas muestrales.

Elección del Area de Estudio

Para la implantación del estudio se seleccionó una zona localizada en el extremo sur de la Península, misma que se encuentra ubicada aproximadamente a 7 Km de Todos Santos. El área de estudio tiene forma de cuadrado de 2 Km por lado y -- una superficie total de 400 Ha, encontrándose parcialmente integrada al Campo Experimental Forestal "Todos Santos" perteneciente al Instituto Nacional de Investigaciones Forestales. La elección de esta área se debió a las razones siguientes: 1) Presentaba vuelos fotográficos recientes a escalas 1:5,000, 1:10,000 y 1:20,000; 2) las instalaciones próximas del Campo Experimental mencionado, permitieron la utilización de la infraestructura existente; 3) dentro del área se encontraron abundantemente las dos especies consideradas; 4) la conformación del datilillo (monocaule y de baja altura) en el área facilitaba la captación de la información y 5) se pudo hacer una diferenciación fisiográfica amplia (plano y montañoso) dividiendo el área aproximadamente en dos porciones iguales.

Selección de los Esquemas de Muestreo

Para la captación de la información de campo se implantaron cinco esquemas muestrales. Estos esquemas se aplicaron al estudio en consideración a que, por una parte ya se habían utilizado en -- bosques de clima templado - frío, y por la otra, en su inclusión se requiere combinar el aspecto técnico con el práctico.

Los esquemas que aquí se proponen, presentan las características siguientes:

Esquema de Muestreo "A" (Fig. 1). Esta constituído por 5 conglomerados dispuestos en forma de cruz; es decir, se ubican en la parte central y en la parte media de cada uno de los lados del área de estudio. Cada conglomerado tiene forma cuadrada; con 200 m dando una superficie de 4 Ha, con espaciamiento equidistante de 700 m en relación al conglomerado central. En la periferia de cada conglomerado se ubican 8 sitios circulares de 0.1 Ha, equidistantes 100 m uno de otro; los sitios suman un total de 40 para toda el área, lo que constituye una intensidad de muestreo del 1%.

Esquema de Muestreo "B" (Fig. 2). Presenta las mismas características del esquema anterior; su diferencia radica en que los conglomerados perimetrales se ubican en los vértices del cuadro que conforma el área de estudio; estos conglomerados se sitúan en forma equidistante a 989.94 m a partir del conglomerado central en forma radial.

Esquema de Muestreo "C" (Fig. 3). Esta --- constituído por líneas de muestreo de 1 Km sobre las cuales se ubican sistemáticamente sitios circulares de 0.1 Ha, espaciados a cada 200 m. Para este propósito se dividió el área de estudio en 4 cuadrantes de 1 km^2, en cada uno de los cuales se ubicaron 10 líneas de muestreo equidistantes 100 m una de otra. En cada cuadrante se seleccionaron totalmente al azar dos de dichas líneas, sobre las cuales se ubicaron sistemáticamente 5 sitios de muestreo. El total de sitios fue de 40 y la intensidad de muestreo de 1.0%.

Esquema de Muestreo "D" (Fig. 4). Es una combinación de A y B integrando un total de 72 sitios, con una intensidad de muestre de 1.8%.

Esquema de Muestreo "E" (Fig. 5). Presenta las mismas características de esquema C, con la diferencia de que en cada línea muestral se ubican

sistemáticamente 9 sitios en lugar de 5, equidistantes 100 m uno del otro, lo que hace un total de 72 para toda el área y una intensidad de muestreo de 1.8%.

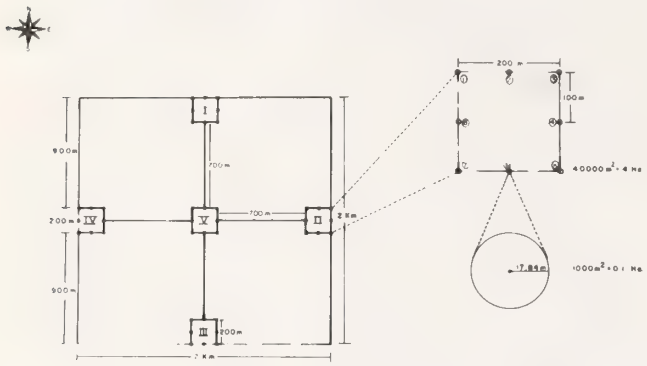

Figura 1.- Características del Esquema A.

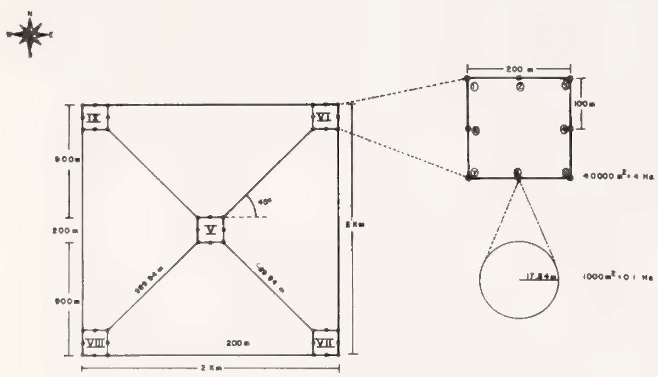

Figura 2.- Características del Esquema B.

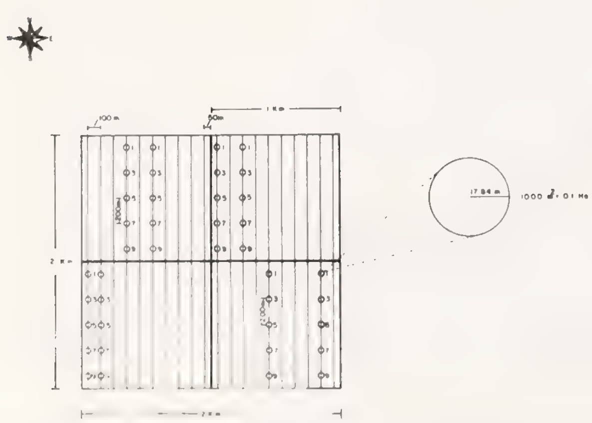

Figura 3.- Características del Esquema C.

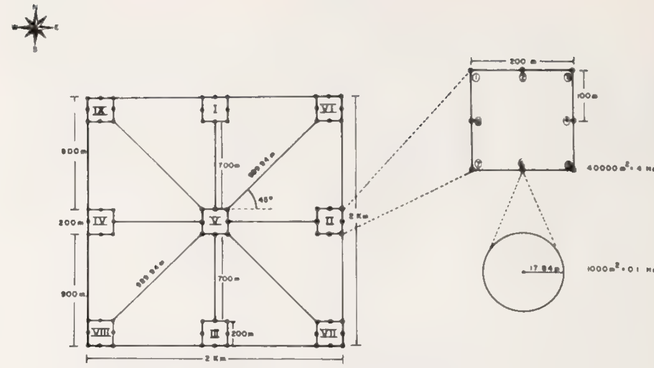

Figura 4.- Características del Esquema D.

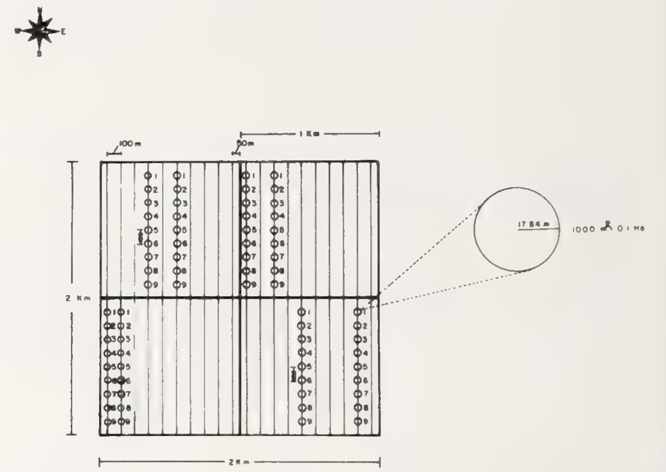

Figura 5.- Características del Esquema E.

Plano de Estratos

Considerando la conveniencia de referir la información a diferentes condiciones del área de trabajo, fue preciso elaborar un plano estratificado escala 1:5,000 (Fig. 6). Para este efecto se consideraron las 5 geoformas siguientes: 1) planicie, 2) depresión, 3) lomeríos, 4) mesetas y 5) barrancas. La diferenciación se efectuó por medio del análisis estereoscópico de fotografías aéreas (pan, blanco y negro) escala 1:5,000 y 1:20,000. Los 5 estratos básicos se dividieron a su vez en subrodales, tomando como base el mesorelieve, la presencia de humedad y las características generales de la vegetación, mismos que se identificaron en base a las formas, texturas y tonalidades fotográficas. El plano de tipos fisiográficos resultante, sirvió para diseñar los esquemas muestrales y el testigo, para el cálculo de superficies por estrato y para la ejecución y control de las actividades de campo.

Caracterización del Testigo

Con objeto de establecer un marco en base al

cual pudieran compararse los resultados obtenidos de los esquemas muestrales, se procedió a caracterizar un testigo (Fig. 7). Para este propósito se calculó primeramente el coeficiente de variación por estrato, tomando como base la información aportada por los esquemas muestrales, encontrándose una tendencia al agrupamiento de algunos de ellos; sin embargo, el estimador anterior reportó agrupaciones no concordantes con el aspecto fisiográfico, al combinar dentro de una misma categoría estratos pertenecientes a la zona plana con algunos de lomeríos y barrancas. Por otra parte, algunos estratos aparentemente similares de planicies, lomeríos y barrancas, presentaron un indicador de incongruencia. En resumen, mediante la aplicación de este estimador se obtuvo una agrupación entremezclada de estratos con características fisiográficas diferentes.

Por las razones expuestas y tomando en consideración características de índole técnica, de disponibilidad de tiempo, de infraestructura disponible y de costos de obtención de resultados, se optó por aplicar una intensidad de muestreo del 10% para caracterizar el testigo. Atendiendo situaciones en relación a la forma, tamaño y variabilidad de los estratos, desplazamiento de estos, sistematización de actividades y dificultad de ubicación de los sitios en las fotografías aéreas, se eligió como esquema de muestreo un diseño constituído por conglomerados de tamaño variable en forma de espiral, con ángulos rectos orientados al norte - sur y este - oeste francos, mismos que siguieron una secuencia en sentido contrario a las manecillas del reloj, a partir de un sitio central. Sobre las lineas que conformaron la espiral se ubicó un número variable de sitios, equidistantes 50 m uno de otro, de forma circular y de 0.1 Ha. La distribución de la muestra fué proporcional al tamaño de los estratos y cubrió prácticamente todas las variaciones presentes en cada estrato (Fig. 7).

Información Derivada de las Unidades Muestrales

Para llevar a cabo el inventario de las especies consideradas y establecer la eficiencia de los esquemas muestrales, se requirió de la obtención de la información siguiente:

Datos Sobre Tiempos Empleados en las Actividades de Muestreo

— Tiempo de delimitación y levantamiento del sitio.
— Tiempo de caminamiento al sitio siguiente.
— Tiempo de caminamiento al conglomerado ó línea siguiente.

Datos de las Características de las Especies

— Altura total.
— Altura del fuste principal.
— Número de ramas (solo en cardón).
— Diámetro del fuste principal.
— Diámetro de ramas (solo cardón).
— Longitud de ramas (solo en cardón).
— Diámetro de roseta (solo en datilillo).
— Longitud de roseta (solo en datilillo).
— Número de brotes (solo en cardón).
— Número de renuevos.

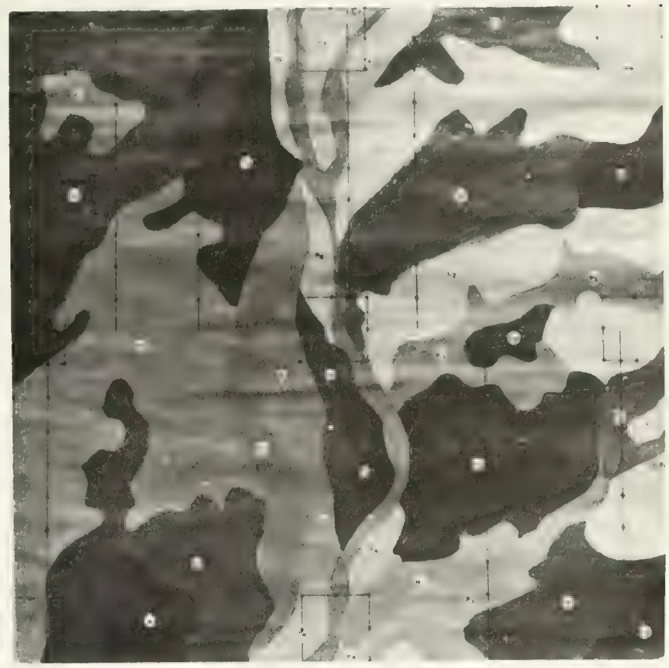

Figura 6.- Plano de la Zona de Estudio con la clasificación de las características fisiográficas presentes.

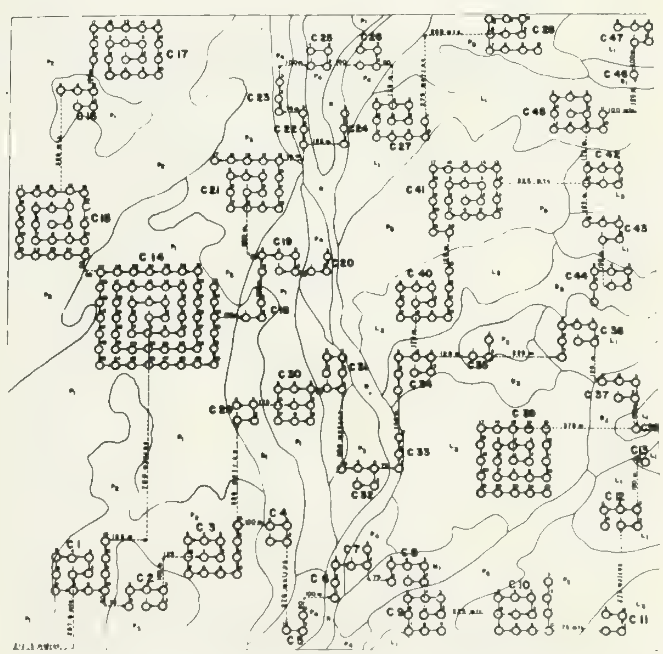

Figura 7.- Esquema de muestreo correspondiente al testigo, en la que el tamaño de la muestra es proporcional al tamaño de los estratos.

Actividades de Campo

Para la captación de los datos se utilizaron dos brigadas constituídas por un Ingeniero Forestal, un Guarda Técnico Forestal y dos Peones. Los integrantes a nivel subprofesional y operativo de las brigadas recibieron un entrenamiento previo, proporcionándoseles además, un instructivo para la toma de información, así como diagramas de secuencia de actividades tanto para los esquemas muestrales como para el testigo. Para la implantación de los sitios y la obtención de la información se utilizó brújula, cable compensado por pendiente, altímetro, pértiga graduada al centímetro, cinta diamétrica y cronómetro. Los datos generados se consignaron en las formas de registro elaboradas para este propósito; ademas, se tomaron fotografías terrestres de cada una de las actividades desarrolladas en el campo.

RESULTADOS Y DISCUSION

Precisión de la Información

Para determinar la precisión de la información obtenida, se manejaron los valores promedios para cada esquema muestral en relación a las variables, número de individuos, altura total y diámetro fustal para datilillo y cardón, mismas que se sometieron a un análisis de varianza. Los resultados obtenidos se muestran en las Tablas 1 y 2.

Tabla 1.- Análisis de varianza de los valores promedio de tres variables, medidas en cardón, para esquemas muestrales y testigo.

FV	GL	SC	CM	F
		Nº DE INDIVIDUOS		
Tratamientos	5	31.31520	6.26304	0.32217
Error	68	1321.91810	19.43997	
Total	73	1353.23330		NS
		ALTURA TOTAL		
Tratamientos	5	0.91908	0.18382	0.53695
Error	68	23.27909	0.34234	
Total	73	24.27100		NS
		DIAMETRO FUSTAL		
Tratamientos	5	0.00223	0.00045	0.63380
Error	68	0.04837	0.00071	
Total	73	0.05060		NS

Los datos de la tabla, indican que no existe variabilidad en cuanto a los datos que se derivaron de los distintos esquemas muestrales y los aportados por el testigo; es decir, no se presenta diferencia significativa entre los diferentes valores promedio para las tres variables consideradas.

Tabla 2.- Análisis de varianza de los valores promedio de tres variables, medidas en datilillo, para esquemas muestrales y testigo.

FV	GL	SC	CM	F
		Nº DE INDIVIDUOS		
Tratamientos	5	139.36758	27.87352	1.265
Error	55	1211.71630	22.03121	
Total	60	1351.08390		NS
		ALTURA TOTAL		
Tratamientos	5	0.42223	0.08445	2.46
Error	55	1.89105	0.03438	
Total	60	2.31328		*
		DIAMETRO FUSTAL		
Tratamientos	5	0.00109	0.00022	2.0
Error	55	0.00621	0.00011	
Total	60	0.00730		NS

Los resultados en la Tabla 2 indican que no se presentó significancia alguna en las variables número de individuos y diámetro fustal; en cambio, si aparece en la variable altura total. Para caracterizar la significancia de esta última variable, fue necesario someter sus valores promedio a una prueba de diferencias entre testigo y esquemas; para ésto, se aplicó la Prueba de Diferencias de Dunnet, obteniéndose los resultados que muestra la Tabla 3.

Tabla 3.- Prueba de diferencias de Dunnet, para los valores promedio de la variable altura total.

TRATAMIENTOS	A	B	C	D	E	T
PROMEDIOS	1.90	2.09	1.96	1.98	1.98	2.14
DIFERENCIAS	0.24	0.05	0.18	0.16	0.16	
SIGNIF.AL 1%	**	NS	NS	NS	NS	
SIGNIF.AL 5%	*	NS	*	*	*	

Con un 99% de confiabilidad puede afirmarse que únicamente el esquema A presentó diferencias con respecto al testigo; se observa también, que con 95% de confianza todos los esquemas, excepto el B, presentaron diferencias al compararlos contra el testigo.

Los resultados de ambos análisis de varianza se presentan en la Tabla 4.

Tabla 4.- Valores de "F" y significancia de los mismos, para las tres variables consideradas en datilillo y cardón.

VARIABLE	CARDON		DATILILLO	
	VALOR DE F	SIGNIFICANCIA.	VALOR DE F	SIGNIFICANCIA.
Nº DE IND.	0.32317	NS	1.27	NS
ALTURA	0.53695	NS	2.46	*(5%)
DIAMETRO	0.63380	NS	2.00	NS

Por último, es conveniente mencionar que se presentó una mayor variabilidad para Datilillo, es decir, σ^2 datilillo > σ^2 cardón.

TIEMPO Y COSTO DE LOS ESQUEMAS

Los tiempos de cada esquema de muestreo y testigo se determinaron en base a los tiempos promedio de levantamiento del sitio, de caminamiento entre sitios y caminamientos entre conglomerados-y líneas, en tanto que los costos de los mismos, se derivaron en base a los salarios que percibidos por los integrantes de las brigadas que desarrollaron los trabajos de campo. Los resultados obtenidos mediante el procesamiento de estos datos pueden observarse en la Tabla 5, y en las Figs. 8, 9 y 10.

Tabla 5.- Tiempos y costos de los diferentes esquemas muestrales y testigo.

ESQ.	Numero de Sitios	Intensidad de Muestreo	Tiempo Tot. Prom./Sitio (Horas)	Tiempo Tot. (Horas)	Costo Tot. Prom./Sitio (Pesos)	Costo Tot. (Pesos)
A	40	1.0%	0.52	20.86	218.77	8750.78
B	40	1.0%	0.63	25.35	265.86	10634.33
C	40	1.0%	0.53	21.19	222.23	8889.22
D	72	1.8%	0.52	37.51	218.55	15735.45
E	72	1.8%	0.38	27.31	159.31	11456.55
T	400	10.0%	0.48	190.68	199.98	79990.27

En la Tabla 5, puede observarse que los tiempos totales promedio por sitio para los esquemas (A, C y D) fueron muy semejantes, en cambio los esquemas B y E presentaron los valores máximos y mínimo respectivamente. En relación a los Esquemas de conglomerados (A, B y D), el mayor tiempo correspondiente al B se debió a que sus caminamientos entre conglomerados fueron mucho más largos que en los otros dos esquemas, en tanto que para los esquemas de líneas (C y E), el menor tiempo del E tiene su origen en su corto caminamiento entre sitios, además de la facilidad de realizar tales caminamientos sobre líneas continuas.

Los costos totales promedio por sitio, se derivaron de los tiempos anteriores y en consecuencia siguen la misma tendencia, pudiendo observarse que el esquema E es el que reportó el costo mínimo. Por último, los tiempos y costos totales están directamente relacionados con el número total de sitios levantados en cada Esquema Muestral.

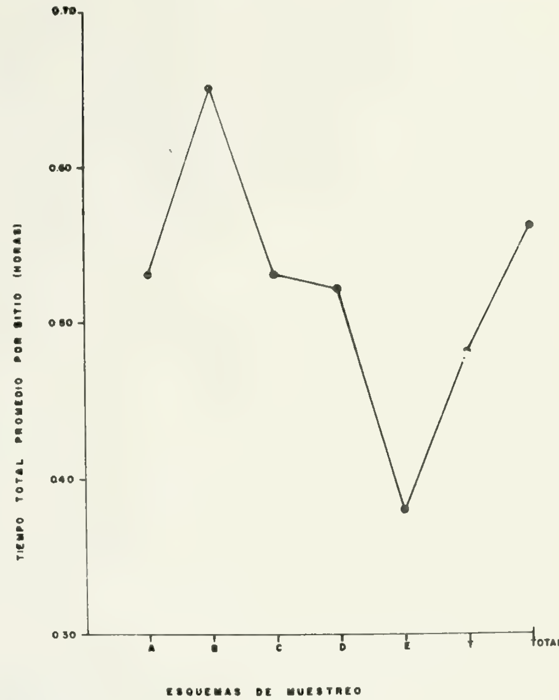

Figura 8.- El esquema de muestreo E requirió el menor tiempo promedio por sitio; el mayor correspondió al esquema B.

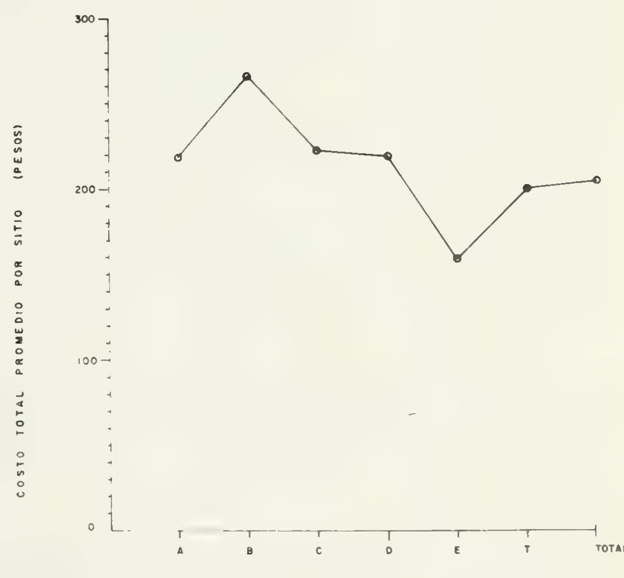

Figura 9.- El mínimo costo total promedio por sitio correspondió al esquema E seguido de cerca por el correspondiente al testigo.

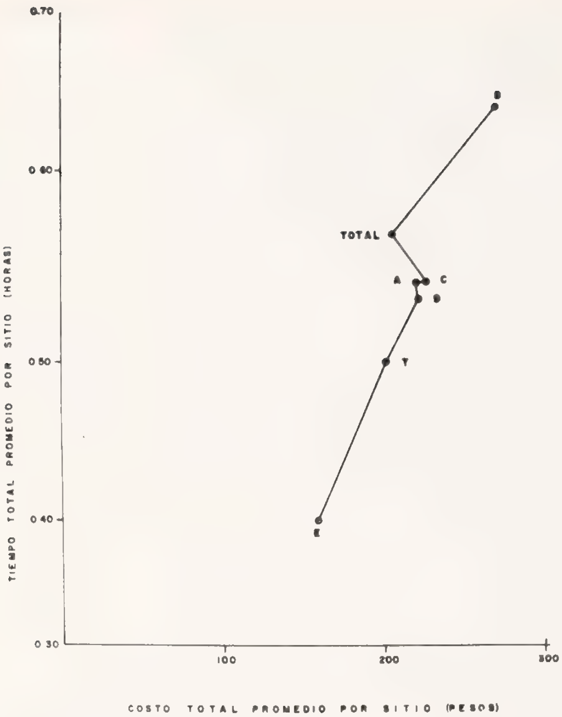

Figura 10.- El esquema E es el que presenta el - menor costo y tiempo por unidad de muestreo; los A, C y D exhiben valores intermedios y - el B los mayores.

CONCLUSIONES

Por lo que se refiere a la precisión de las- tres variables medidas en datilillo y cardón, los resultados indican que no existe diferencia significativa en la información reportada por los cinco esquemas de muestreo, en relación a la del testigo. Por lo anterior, consideramos que en la -- práctica podría utilizarse indistintamente cualquiera de los aquí empleados.

Aún cuando el esquema E aparece como el más- barato por unidad muestral, en realidad resulta - más caro (a nivel de esquema) que los A, B y C, - debido a que aquel requiere 72 sitios, mientras - que éstos contienen solamente 40.

En virtud de que los esquemas C y E utilizan líneas de muestreo ubicadas al azar, los tiempos- y costos de su aplicación en trabajos prácticos,- deberán ser muy diferentes de los aquí reportados ya que al efectuarse nuevos sorteos, estas líneas adquirirán nuevas posiciones.

Ya que los esquemas de conglomerados con -- 1.0% de intensidad de muestreo no presentan el -- problema de los esquemas de líneas, resultan serlos más prácticos, especialmente el esquema A, -- por su menor costo por sitio.

Considerando que en México no se ha efectuado aún el inventario de la vegetación desértica a nivel nacional y regional, creemos que el esquema A puede considerarse como una alternativa factible, si se constituye como una unidad de muestreo para llevar a cabo este tipo de inventarios.

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ABSTRACT

The urgent need to incorporate the vegetation of the Mexican desert into the economy requires the production of practical and efficient sampling methods to inventory useful wildlife species. In this work, five different sampling schemes are compared for two widely distributed species in the Baja California peninsula. The results obtained by analyzing their efficiency in relation to time and application cost, and the precision of the information obtained from them is discussed here.

Estimaciones de Biomasa a Partir de la Altura y la Cobertura de Plantas Xerófilas[1]

González-Medrano, F.[2]; A. Castillo;

G.R. Durán; C. Martínez del Río

y J. M. Quintanilla[2.2]

Resumen.- Con medidas simples como altura y cobertura de las plantas se hicieron estimaciones de biomasa, para Agave stricta, A. marmorata, A. xylonacantha y para Hechtia podantha. Las ecuaciones de regresión son útiles para cada especie, sobre todo si la forma de vida es uniforme. Las ecuaciones obtenidas pueden emplearse para la estimación de rendimientos potenciales (standing crop) de especies de importancia económica.

INTRODUCCION

Los ecosistemas de zonas áridas y semiáridas se consideran dentro de aquellos más frágiles. El delicado equilibrio logrado a través del tiempo entre los componentes del ambiente y las comunidades bióticas, fácilmente se ve modificado por alterac iones, principalmente de origen antropógeno. Por tanto, la explotación de recursos naturales renovables, en estas regiones, requiere de una mayor cautela, pero no sólo una mayor cautela, sino un conocimiento más profundo de su dinámica, de su capacidad de explotación y de su capacidad de recuperación.

Dentro de este contexto, la inventarización adecuada de los recursos adquiere una relevancia notoria.

Las estimaciones de productividad y biomasa generalmente se hacen por el método de cosecha, que presupone la destrucción del recurso a evaluar. Uno de los métodos no destructivos, para estimar la biomasa, es aquel que establece una relación entre medidas de la planta fácilmente obtenibles y la biomasa, técnica que se conoce como análisis dimensional, Newbould, (1967) y Whittaker, (1966). Estas técnicas han sido usadas para evaluar recursos forestales empleando medidas simples, diámetro a la altura del pecho (DAP) y altura. Pero estimaciones de la biomasa de arbustos usando análisis dimensionales son escasos; destacan los realizados por Kittredge (1945) en Ceanothus y Arctostaphylos, los de Medin (1960) en Cercocarpus, los de Mason y Hutchings (1967) en Juniperus, de Burk y Dick-Peddie (1973) y Chew (1965) en "gobernadora" (Larrea tridentata), usando los valores de la cobertura para predecir la biomasa.

En 1975, Ludwig, Reynolds y Whitson, usaron para plantas desérticas análisis de regresión para estimar el peso seco del follaje, tallos vivos y muertos, además de raíces, a partir del área de la copa y el volumen. Los resultados obtenidos muestran que el volumen y el área de la copa son estimadores adecuados de la biomasa.

Las ecuaciones empleadas para Larrea, comparadas con las empleadas por otros autores, para otra localidades, sugieren que los resultados podrían aplicarse a otras zonas desérticas, cuando menos para especies de forma de crecimiento definidas y poco variables. Estos autores trabajaron con arbustos xerófilos muy característicos del desierto chihuahuense:

Larrea tridentata
Flourensia cernua
Prosopis glandulosa
Ephedra trifurca
Ephedra torreyana

[1] Trabajo presentado en el SIMPOSIUM of Arid Land Resource Inventories. Nov. 30-Dic. 6, 1980. La Paz, México.

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Xanthocephalum sarothrae
Zinnia acerosa
Yucca elata

Salvo esta última que es crasa, ninguna de las otras es carnosa.

En este trabajo se pretendió hacer una estimación de la biomasa con medidas simples y que no impliquen la destrucción de la planta. Se emplearon medidas de altura y cobertura, con las cuales se calculó el volumen de la planta empleando diferentes fórmulas, asumiendo que las formas de vida presentan una determinada forma geométrica, conos invertidos, cilindros, esferas o semi-esferas etc.

Los autores de este trabajo usaron plantas crasirrosulifolias espinosas de los géneros *Agave* y *Hechtia*.

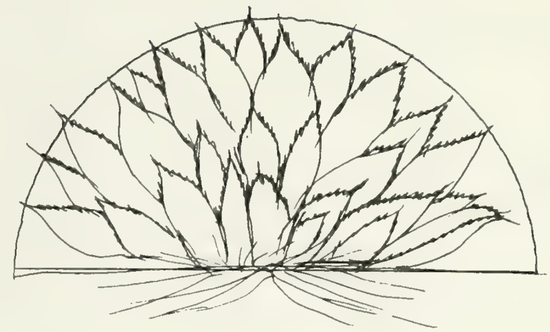
METODO

Los ejemplares fueron colectados en las zonas áridas de Hidalgo y Tehuacán. *Agave xylonacantha* fue colectado en un matorral mediano subinerme con *Cephalocereus senilis* a 4 Km. al este de Mezquititlán, Hidalgo, sobre un sustrato de lutitas; *A. marmorata*, fue colectada a 8 Km. al norte de Chazumba, Oaxaca, en un matorral mediano subinerme sobre sustrato yesoso; *A. stricta*, se colectó 1 Km. al noreste de Acatepec sobre la carretera Tehuacán-Huajuapan, formando parte de cercas de cultivo y sobre un sustrato calizo, y *Hechtia* a cuatro kilómetros al sudeste de Zapotitlán de las Salinas en una comunidad de matorral alto crasicaule. Las colectas fueron realizadas entre el 1o. de junio y el 10 de julio al final de la temporada de secas.

Fueron colectados entre 20 y 25 ejemplares de cada especie, procurando que estos cubrieran el rango total de tamaños de la población. De cada individuo se obtuvo el diámetro, la altura y la forma. Todas las partes aéreas fueron cosechadas, marcadas y colocadas en bolsas de papel para su transporte y posterior secado. Todo el material fue secado en hornos con ventilación, a una temperatura de 80°C. durante catorce días y pesado hasta la décima de gramo más cercana.

Análisis de los datos

El volumen de cada planta se calculó usando la fórmula del volumen del hemisferio superior de un esferoide, que es el sólido que mejor se ajusta a la forma de este tipo de plantas (fig. 1)



Para cada especie se elaboró una gráfica de volumen contra peso húmedo y volumen contra peso seco. Utilizando un modelo lineal y la técnica de mínimos cuadrados se calcularon las relaciones para cada especie, entre volumen vs. peso húmedo, y volumen vs. peso seco.

Los parámetros a,b (ordenada al origen y pendiente) de las rectas (peso húmedo) = b (volumen) + a y (peso seco) = b (volumen) + a, fueron calculados de acuerdo con las siguientes fórmulas tomadas de Sokal y Rohlf (1969):

$$b = \frac{\sum^n (x-\bar{x})(y-\bar{y})}{\sum^n (x-\bar{x})^2} \quad y \quad a = \bar{y} - b\bar{x}$$

donde x= volumen, y = peso (húmedo o seco),

$$\bar{y} = \frac{\sum^n y}{n}, \qquad \bar{x} = \frac{\sum^n x}{n}$$

con n = al tamaño de la muestra (# de ejemplares).

Para cada recta se calculó el error standard con el 95 % de límites de confianza, utilizando la siguiente fórmula:

$$ES = \left[\sqrt{\frac{\sum^n (y\text{calculada} - y\text{estimada})^2}{n-2}}\right] x (1.96)$$

El coeficiente de correlación (r), se calculó utilizando:

$$r = \frac{\sum^n (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}}$$

RESULTADOS

El tamaño y biomasa característicos de las especies trabajadas están dados en la tabla 1.

Especie	Ind. (#)	Volumen promedio (cm³)	Peso hum. (gr)	Peso seco (gr)
Agave xylonacantha	20	173,863	1,661	377
Agave marmorata	24	458,404	4,753	683.2
Agave stricta	23	44,957	2,352	627.8
Hechtia podantha	24	50,690	783	241.9

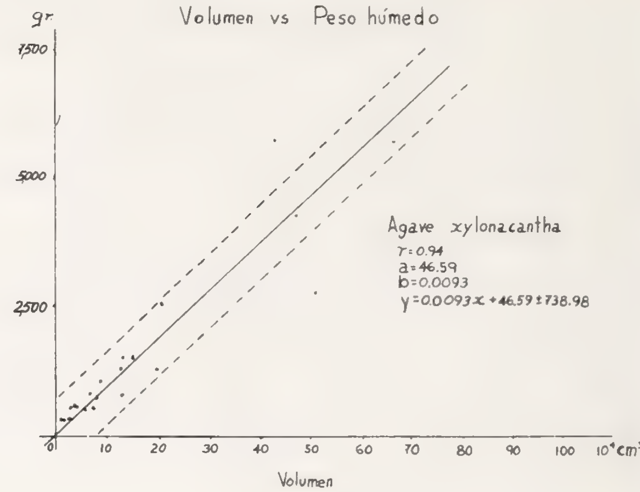
La ecuación de regresión por especie para peso húmedo se muestra en la tabla II, y en la serie I de gráficas.

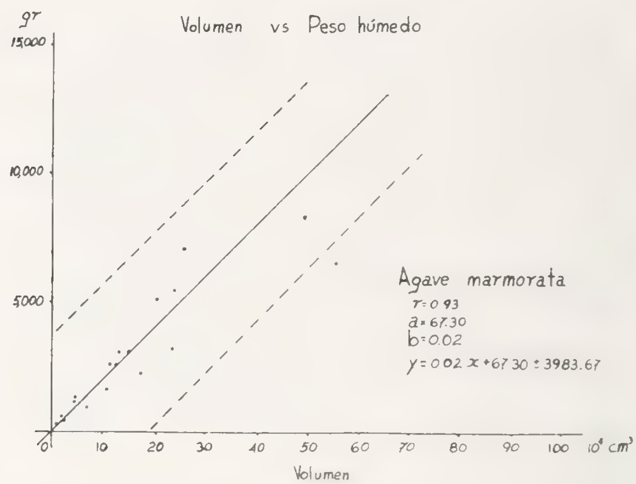
Especie	Ecuación	r	E.S.
Agave xylonacantha	Y=0.0093X+46.6	0.94	738.9
Agave marmorata	Y=0.02X+67.3	0.90	3983.6
Agave stricta	Y=0.05X-137.5	0.89	1124.0
Hechtia podantha	Y=0.014X+86.3	0.89	400.0

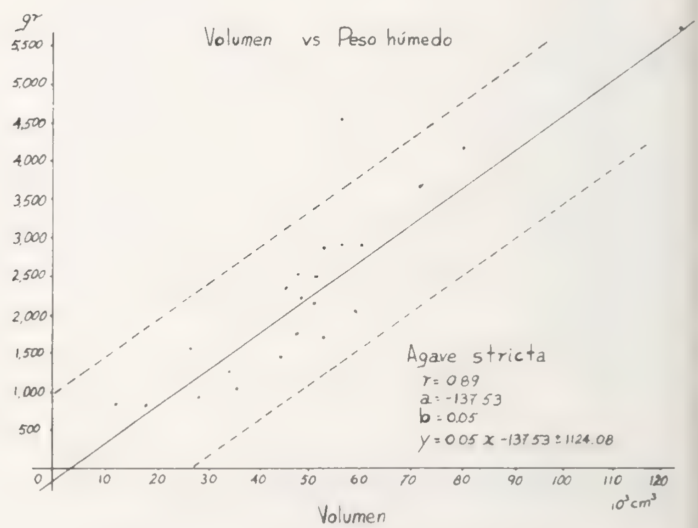
Para peso seco las ecuaciones se muestran en la tabla III, y en la serie II de gráficas.

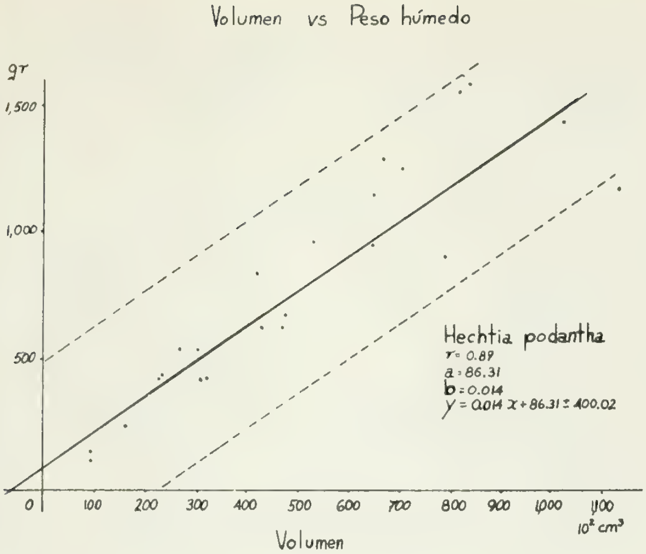
Especie	Ecuación	r	E.S.
Agave xylonacantha	Y=0.0031X-17.55	0.87	500.2
Agave marmorata	Y=0.0017X+246.5	0.72	537.2
Agave stricta	Y=0.01X+168.37	0.81	222.7
Hechtia podantha	Y=0.004X+36.63	0.76	196.3

Serie I. Gráficas obtenidas a partir de los valores que se presentan en la tabla II.

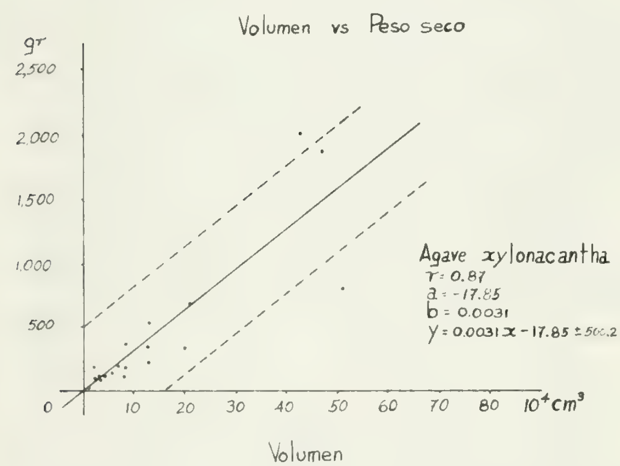


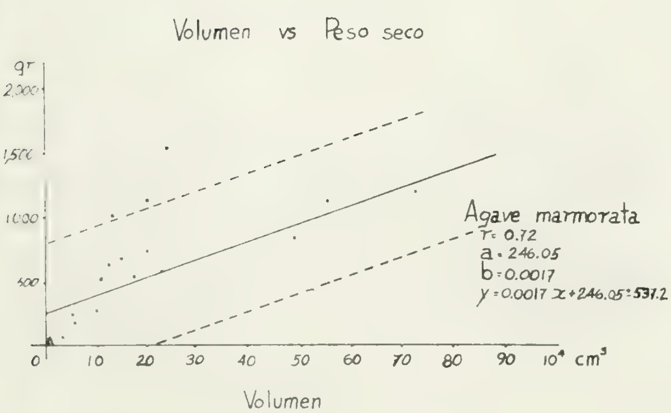


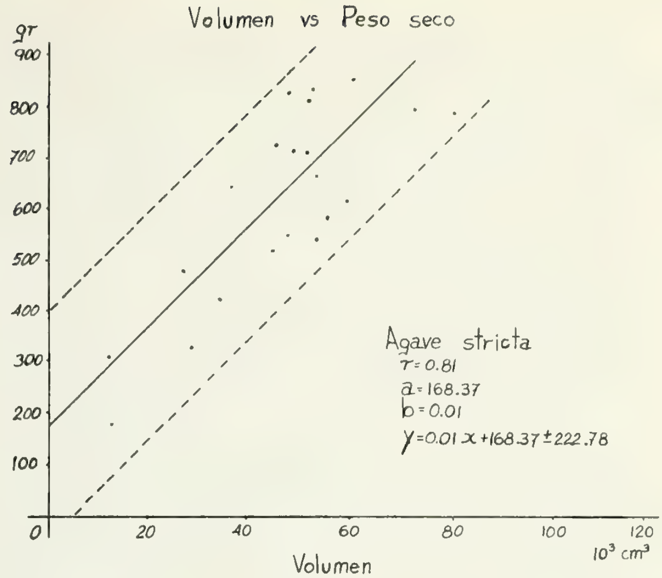


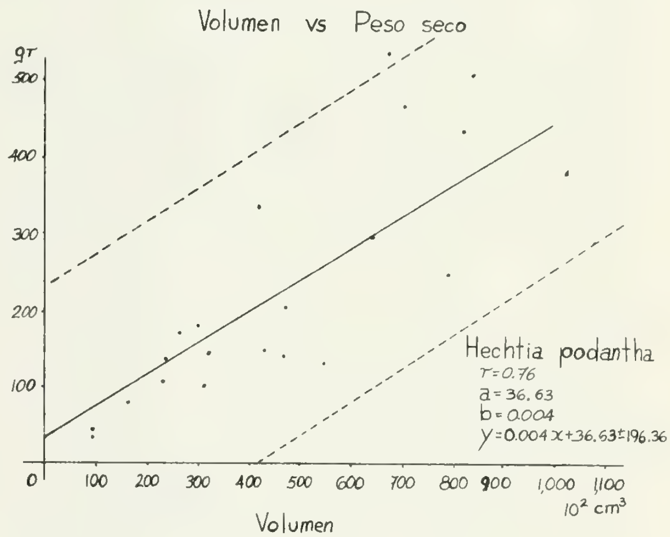


Serie II. Gráficas correspondientes a los valores de la tabla III.









DISCUSION

Las ecuaciones de volumen-biomasa obtenida en trabajos anteriores para plantas de zonas áridas son en general de arbustos Burk y Dick-Peddie (op. cit.), Ludwig et al. (op. cit.), el uso de esta ecuación con crasirosulifolios introduce algunos problemas que es necesario destacar:

1. En las ecuaciones de regresión el coeficiente de correlación es significativamente mayor ($P < .01$) utilizando una prueba de T tomada de Bailey (1964) en las regresiones de peso húmedo que en las de peso seco, esta diferencia es debida a la mayor desviación de los valores a la recta teórica.

Es posible observar en las gráficas que es en los valores altos en donde se da esta variación; esto es debido a que en las plantas grandes el secado se dificulta por el alto contenido de agua y la impermeabilidad de las cutículas.

2) Las regresiones de volumen-peso húmedo resultan en general poco confiables pues las plantas crasas de zonas áridas tienen la capacidad de aumentar su peso notablemente en poco tiempo sin que los parámetro, cobertura y altura, usados para calcular el volumen, cambien.

3) Las diferencias en el parámetro b (pendiente), para diferentes especies en general reflejan diferencias en la densidad de las plantas ya sea en la densidad de las hojas o en la cantidad de agua en las hojas. En el primer caso, es notable la diferencia que existe entre las pendientes de la regresión de volumen vs. peso seco. En *Agave stricta* la distribución de hojas es uniformemente densa dentro del volumen en el cual se encuentra la planta mientras que el *Agave xylonacantha*, *A. marmorata* y *Hechtia podantha* las hojas se distribuyen en forma de roseta y se concentran en el cogollo de la planta.

4) Estas diferencias mostradas en los valores de las pendientes nos indican que, a pesar de tratarse de especies de un mismo género y de una misma forma de vida, no es posible hacer extrapoblaciones de una especie a otra, es decir, que los parámetros a y b de la regresión son uniespecíficos y quizá aplicables a otras poblaciones dentro de la misma especie con una forma de vida más o menos uniforme tal como fue demostrado por Ludwig et al. (op. cit.) con los valores obtenidos para *Larrea tridentata*, al comparar diferentes poblaciones.

CONCLUSIONES

Aunque para el caso de formas de vida crasirrosulifolias espinosas el esfuerzo requerido en cosechar y procesar gran cantidad de material para desarrollar las ecuaciones predictivas de volumen contra biomasa es grande, (sin embargo) las regresiones obtenidas pueden ser utilizadas en la estimación de rendimientos potenciales (standing crop). Sobre todo en la explotación de especies económicamente útiles pueden ser una herramienta muy importante en la toma de decisiones pues proveen de una estimación a priori de la biomasa potencial de la especie, aun más si esta metodología se complementa con estimaciones adecuadas de la densidad de las poblaciones a nivel regional.

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ABSTRACT

Biomass estimates were made for *Agave stricta*, *A. marmorata*, *A. xylocantha* and *Hechtia podantha* using simple measurements such as height and vegetative cover. Regression equations are useful for each species, especially if there is uniformity in the lifeform. The equations obtained may be used to estimate potential yields (standing crop) of species of economic importance.

Efficient Measurement of Arid Zone Vegetation Utilization[1]

Neil E. West [2]

Abstract.--Conventional methods of assessing vegetation utilization were developed in forest or grassland contexts. Sparseness of vegetation, its low and erratic productivity, and variable utilization force adoption of different techniques for deserts. Allometry relating dimensions of remaining parts to probable harvested portions shows promise as a cost effective estimate of vegetation utilization.

INTRODUCTION

The sparseness of desert vegetation and its generally low but erratic productivity make it difficult to economically justify intensive methods of inventory. Arid regions, especially those with heterogeneous topography, exhibit considerable diversity in plant community structure and thus patchy, selective utilization by man through his machines and animals. Since this diversity is spatially dispersed across vast areas, adequate samples in conventional statistical terms require more sampling then where plants are placed more closely together and are compositionally more homogeneous. The vegetation scientist working in deserts is thus usually caught on the horns of a dilemma of how to obtain statistically reliable data at costs commensurate with the economic value of the resource.

Other contributors to this volume have dealt with the problems of designing efficient means of stratifying landscape heterogeneity and assessing phytomass. My task is to address the problems of estimating utilization.

DEFINITIONS

Utilization refers to the amount of plant material that this removed by man or animals. Utilization is usually expressed as a percentage of the standing crop phytomass or annual production that is removed from the place where it grew. Absolute measures (e.g., kg ha^{-1}) of utilization may also be used. Utilization is either expressed on a per plant or per unit area basis. The latter becomes more difficult when numerous species and life forms are encountered on a given plot of ground. If the level of utilization is known that will allow biological recoverability, then estimates of further allowable use or prospects for damage to the renewability of the vegetation may be arrived at.

MODES AND AGENTS OF UTILIZATION

The mode of utilization in deserts might vary from complete removal off site to simple on site transfer to standing dead or litter. Major agents of utilization would be livestock and wildlife consumption of forage, tires of off-road vehicles and collection of parts of or entire plants for ornamental, ceremonial, or industrial uses. Although we most commonly think of off-site transfer of plant materials by man and his domestic animals, we also have to consider any on-site transfer of phytomass from living or standing dead (any upright plant portion, e.g., wood) to the prostrate, litter compartment of ecosystems, e.g., trampling. Also, we have to be able to recognize the role of wild vertebrates and invertebrates and storms in affecting these transfers. For instance, hares (Lepus spp.) commonly nip off much more material than they actually ingest (Currie and Goodwin 1966). This action, however, greatly influences what is left for other potential users and how the plants will regrow.

CONVENTIONAL MEANS OF MEASUREMENT

Most efforts to measure utilization have centered on the consideration of current annual production (Barnes 1976). This is proper in the case of grass or forb-dominated vegetation. In deserts where perennials prevail and growth is less dependable, then animals and man must rely

[1] Paper presented at the symposium on arid land resource inventories: Developing cost-efficient methods. [LaPaz, Mexico, November 30-December 6, 1980].

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on past as well as current years' growth. Growth of desert trees, shrubs, and succulents is not at all as predictable or morphologically distinguishable into annual and previous growth as for herbs (Orshan 1964, 1972). Accordingly, we do not find the conventional definitions as satisfactory in deserts.

The low productivity, spatial heterogeneity and patchy, selective use of desert vegetation also greatly increases the sampling variation for comparison of used with unused sites. For instance, the required number of exclusion cages or paired plots for statistically adequate weight estimates of utilization (Stoddart et al. 1975) almost always becomes unreasonably large in arid contexts. Similar problems develop if stems and twigs are marked and observed at a later date. Simple one-time assessment of the percentage of used stems or twigs does not relate linearly to total plant utilization, particularly at very low (Rutherford 1979) or very high levels of use (Stickney 1966, Jensen and Scotter 1977). The method of percentage of used plants is also deceptive because some plants get used completely or are partially used more than once and regrowth can occur between the incidences of use.

All of the methods that attempt to guage the amount used rely on estimates of what was once present. If that was not directly measured, then considerable extrapolation is necessary. Heady (1975) favors methods that sress quantity of mateial that remains rather than proportion of the crop, since that is the portion that initiates new growth and indicates continued good health of the vegetation.

Amounts of vegetation left after use can be measured directly and standards of utilization based on these amounts can eliminate the inaccuracies of estimating the proportion of the standing crop that has probably disappeared. Thus measurement of stubble height, percentages of ungrazed plants, and weights of a random sample of both used and unused plants is suggested as a better means of gauging utilization. This approach works well if the degree of utilization is moderate and full evidence of the presence of utilized plants is left. If, however, plants have been dug out of the ground completely, such as by cactus rustlers or charcoal makers, there may be no evidence of use remaining.

It is of course much easier to cast degrees of utilization into categories or classes than to gauge utilization into continuous terms, either on relative or absolute scales. Walker (1976) suggests the use of a computer-compatible recording of estimates of utilization/reduction in classes that are more sensitive toward the upper and lower extremes of the whole range than any percentage of marked or randomly selected plant population approach. Classes may be derived from empirical studies where double sampling of actual weights or degree of utilization is both occularly estimated and measured on a sub-sample of plots or individuals.

NEWER APPROACHES

Relatively reliable estimates of utilization with moderate time expenditures has been realized by use of regression techniques relating plant dimensions to each other (Barnes et al., 1976; Ferguson and Marsden, 1977; Bowns, 1979; Rutherford, 1979; Provenza and Urness 1981). Since the fitting of equations using untransformed data is unique for each instance, there has been considerable search for transformations yielding linear, species-wide relationships. Transformations of various dimensional data into natural logarithms and exponential forms (the allometric equation) has generally provided this improvement (Whittaker and Marks 1975). These approaches have thus afforded a way of using an easily measured portion of a plant to predict its foliage weight (Fig. 1). Similar relationships are found on a twig basis (Fig. 2). Thus one has to only measure a basal portion of used twigs or stem to estimate how much was taken and escapes having to mark plants before use. The only problems are having a part of each used plant left and assuming that all of the plant above the severed base was alive and healthy. Since this is not always true, especially for desert plants, further improvement of this approach is made by estimating the cross-sectional area of live conducting tissue and relating it to foliage (Tausch 1980). This

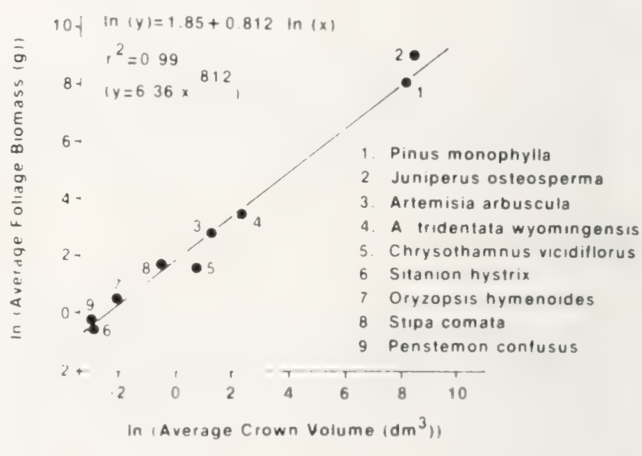

Figure 1. Relationship of foliage biomass to crown cover volume of two tree , three shrub, three grass and one forb species at a pinyon-juniper woodland site, southwestern Utah (from Tausch 1980).

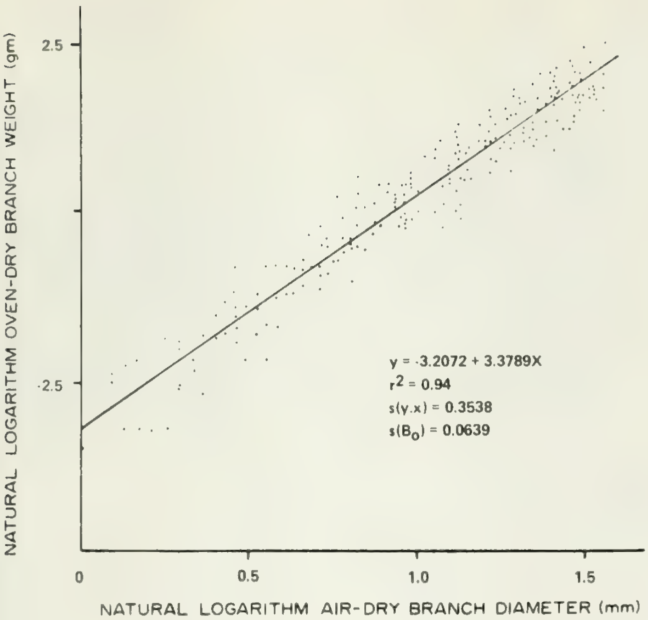

Figure 2. Relationship of oven-dry twig weight to air-dry twig diameter for Coleogyne ramosissima at a southwestern Utah site (from Provenza and Urness 1981).

approach has a physiological, rather than totally empirical basis. That is, the amount of live leaf tissue is directly and deterministically related to how much water and nutrient transport tissue exists at the base of the plant part. This promising approach is currently undergoing further development on our campus. We expect to have recommendations for its practical employment available shortly.

CONCLUSION

Although conventional, extensive methods of estimating utilization require less time than other methods, they lack accuracy. Conversely, before and after measurements usually provide reliable data but are tedious, require large sample sizes, and are thus expensive. Without definition of objectives and priorities in a given endeavor, it is impossible to conclude what conventional method might be appropriate. Since some of the quicker conventional methods may not provide information of sufficient reliability, one could always ask whether a scientific-based survey should even be attempted. Arbitration through a neutral third party would have to be considered as an alternative if gathering of adequate data is uneconomical. Development of allometric approaches shows considerable promise for simplifying the task of estimating utilization and thus may allow accurate, yet cost-efficient data for arid, as well as other contexts.

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RESUMEN

En zonas aridas de vegetación esparcida, producción erratica y utilizacion variable, los métodos convencionales carecen de precision dado el diferente contexto ecológico donde fueron desarrolladas. En contraste las medidas antes y después, si bien proven consistente información, son tediosas, requieren un mayor numero de muestras y resultan caras. La transformación técnica a formas logarítmicas y exponenciales se muestra prometedora en la tarea de simplificar la estimación de la utilización e incrementar la eficiencia economica de la toma de la toma de datos en condicions de aridez.

Community Structure Analysis - A Rapid, Effective Range Condition Estimator for Semi-Arid Ranges[1]

Charles P. Pase[2]

Abstract.--The CSA method can be used to estimate a plant's relative position within a community by an Importance Value based on cover, density, and frequency. The IV is theoretically little affected by year-to-year fluctuations in precipitation. Field tests indicate minor differences between observers. Change in IV indicates change in range condition.

COMMUNITY STRUCTURE ANALYSIS--A RAPID EFFECTIVE RANGE CONDITION ESTIMATOR FOR SEMI-ARID RANGES

In recent years, actual measurement of plant community attributes has become increasingly sophisticated, and now largely replaces the descriptive or qualitative methods used by pioneer ecologists. Although often as subject to bias as older qualitative methods, the newer methods have three important characteristics: (1) they can be repeated with a measurable consistency, (2) sampling error can be determined and reliability evaluated, and (3) the quantitative results can be tested readily by statistical methods.

Descriptive Analytic Concepts in Community Structure Analysis

Plant communities may be described at any given point in time by a variety of characteristics. The method selected is usually tailored to fit that facet of the community thought to be most pertinent to the specific goals of the study--livestock production, wildlife habitat, water use, soil protection, or esthetics. A holistic look at the plant community, however, must consider as many community characteristics as possible in an attempt to recognize and interpret the uniqueness of the community, and to recognize the intraspecific relationships of community components. These elements of community structure describe the uniqueness of the community when considered in the aggregate that is often missed when each element is considered in isolation. Such synthesis, of course, carries a risk of oversimplification or improper weighting, and must be used with care.

Density

In modern ecological usage, the term density means the number of individuals per unit area or volume. Actual counts of individuals of a species or class are needed per plot of known size. For most plant species, individuals are readily distinguished. As Daubenmire (1968) has pointed out, however, most communities contain some species that reproduce vegetatively, and determination of what constitutes a plant unit in such cases is somewhat arbitrary. For rhizomatous grasses such as western wheatgrass (Agropyron smithii), each culm or culm group can be visualized as an actual or potential plant unit, as can rooted stoloniferous units of such species as vine mesquite (Panicum obtusum). Mat or sod-forming plants such as blue grama (Bouteloua gracilis) or alkali sacaton (Sporobolus airoides) usually start growth as small, distinct clumps, but may spread to plants a meter or more in diameter. As this occurs, however, the clumps tend to fragment into more-or-less separate

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[1]Paper presented at the symposium, Arid Land Resource Inventories: Developing Cost Efficient Methods, November 30 - December 6, 1980, LaPaz, Mexico.

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units, and it is these separate units that should be counted as actual or potential individuals.

Dominance

The size of a plant in many instances exerts more influence on the community than does the number of plants, for plants even of the same species may differ a hundredfold in size. Stressing plant size in an analysis recognizes this most important component of community structure. The mass of a species, however determined, represents in no small measure the adaptation of the species to the site, as well as its interaction with other species in the community.

Dominance may be expressed in a number of ways, depending on the physical form of the plant species, or upon theoretical or practical limitations of measurement. Basal area is a commonly used measurement for trees, while phytomass or standing crop may be the ideal method for herbaceous plants. From a practical standpoint, cover provides an easily measured characteristic that expresses the influence a species exerts on other community components, and on the site itself in terms of site utilization and protection from erosion.

Frequency

Density and dominance data are important in describing plant communities, but they give no indication as to whether the species is well distributed over the site, or occurs only in infrequent (although perhaps large) units. The number of plots or sample units on which a species occurs is termed frequency, and indicates how generally a species is distributed without regard to size or number. Foresters commonly use the percentage of "stocked plots" as a measure of regeneration success, because the spacing of the regeneration is as important as the number of individuals. A large number of pine seedlings, for example, may be of no more benefit than a small number that is well distributed. In the same sense, frequency aids in delineating a species' role in the community, particularly when considered in conjunction with dominance and density data.

Importance Value

The "importance value" or IV of a species is a composite "score" representing the relative importance of that species in the plant community (Phillips 1959, Dix 1961). While in a sense it is like adding apples and oranges, such composite scores are often helpful in reducing complex data sets to a single, easily understood value. Because of the large number of species with widely contrasting physical characteristics, use of any one element of community structure to describe the vegetation could result in over- or underestimating an individual species' contribution to the community. For example, in one semiarid plant community on the Rio Puerco in New Mexico, western wheatgrass could be most important based on density, blue grama most important based on cover, big sagebrush (Artemisia tridentata) most important based on phytomass, and galleta (Hilaria jamesii) most important based on frequency. A composite IV score based on relative values for cover, density, and frequency, however, would tend to de-emphasize the unique characters that exaggerate a plants' importance.

Importance Value as commonly used attempts to assess the relative importance of plants in a stand, thus permitting an array of species from "most important" to "least important" in the community. One weakness, as pointed out by Daubenmire, is the heavy weight (1/3) given frequency, even though this structural element is probably less important in range evaluation than either dominance or density. There is no reason, of course, why all three elements should have equal weight, and in some instances, a 3:2:1 (or other) ratio for cover, density, and frequency could be used.

CSA Method

Importance Value, as used in the method proposed here, is the sum of the relative dominance (cover), relative density, and relative frequency for each species in the stand. The sum of the IV's for all species in a stand, then, is 3. Cover is based on projected crown cover from transect samples using 5 x 10 cm rated microplots (fig. 1) (Morris 1973). In semiarid mixed communities, we have found the rated microplots to be quite efficient and reproducible, although in shrub communities, the 20 x 50 cm plot proposed by Daubenmire (1959) might be superior. Density is based on individuals per m^2 circular plot. Frequency is the relative number of "stocked" m^2 circular plots.

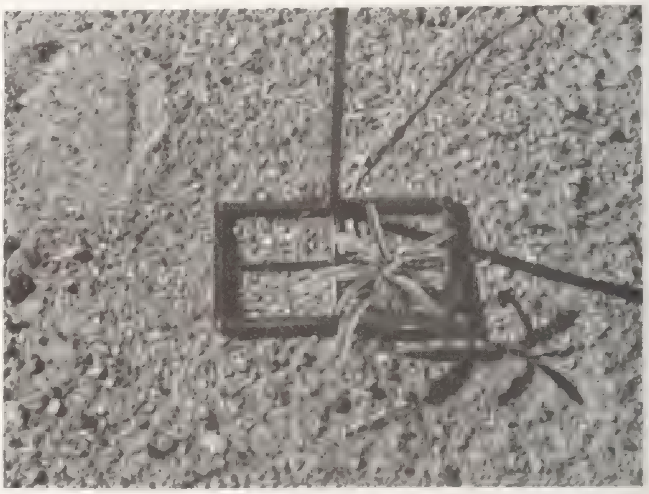

Figure 1.--Estimating canopy cover using a 5 x 10 cm microplot. The plot subdivided to aid in estimating cover classes.

Preliminary checks suggest three over-riding advantages of the present synthesis: (1) because IV is based on "relative" rather than "absolute" values, it is less affected by estimator bias, as an observer who tends to estimate Species A and B high, will also tend to estimate high for other species also; (2) the relative position of a plant in the community array is less disturbed by year-to-year differences in rainfall, as climatic variations tend to affect all species in the same direction, if not quite in the same magnitude, and (3) displacement of a specific IV in the array of IV's for a stand results from some differential ecological pressure against that species, such as differential grazing pressure, and is thus an estimator of changes in the plant community, or "range condition". Some species, of course, are less tolerant of prolonged drought than others, and displacement of the IV of such species must be evaluated in light of precipitation patterns. Recent work at New Mexico State University, for example, suggests that broom snakeweed (Gutierrezia sarothrae) decreases sharply after 2 or 3 years drought, and such a decrease, indicated by a drop in its IV, may not indicate of itself an improvement in range condition. In the last analysis, there is no substitute for careful, experienced interpretation of the data.

Annual species in arid or semiarid areas can fluctuate a hundredfold from year to year in both cover and density solely because of variation in precipitation. Their inclusion would unnecessarily distort the IV's of all other species without shedding any light on range condition changes, and hence are excluded from measurement.

CSA Field Procedure

We have found the following field procedure useful in analyzing and describing range vegetation in the semiarid Rio Puerco basin in northwestern New Mexico. The procedure has been successful for the two seasons it has been in use, but modifications may well prove necessary as the method is extended to other areas (fig. 2).

1. Locate Community Structure Analysis (CSA) transects randomly within "primary use areas" or "key areas", using rectangular coordinates and a base map of the area. A "random course" could also be used.

Mark transects with a steel fence post, identified by a numbered metal tag attached to the post. Pin-point the transects on aerial photos, or on large-scale topographic maps.

Where more than one vegetation type, range site, or soil type is found in one key area, keep the transects separate for analysis. These subdivisions, when they occur, will thus represent homogeneous response units.

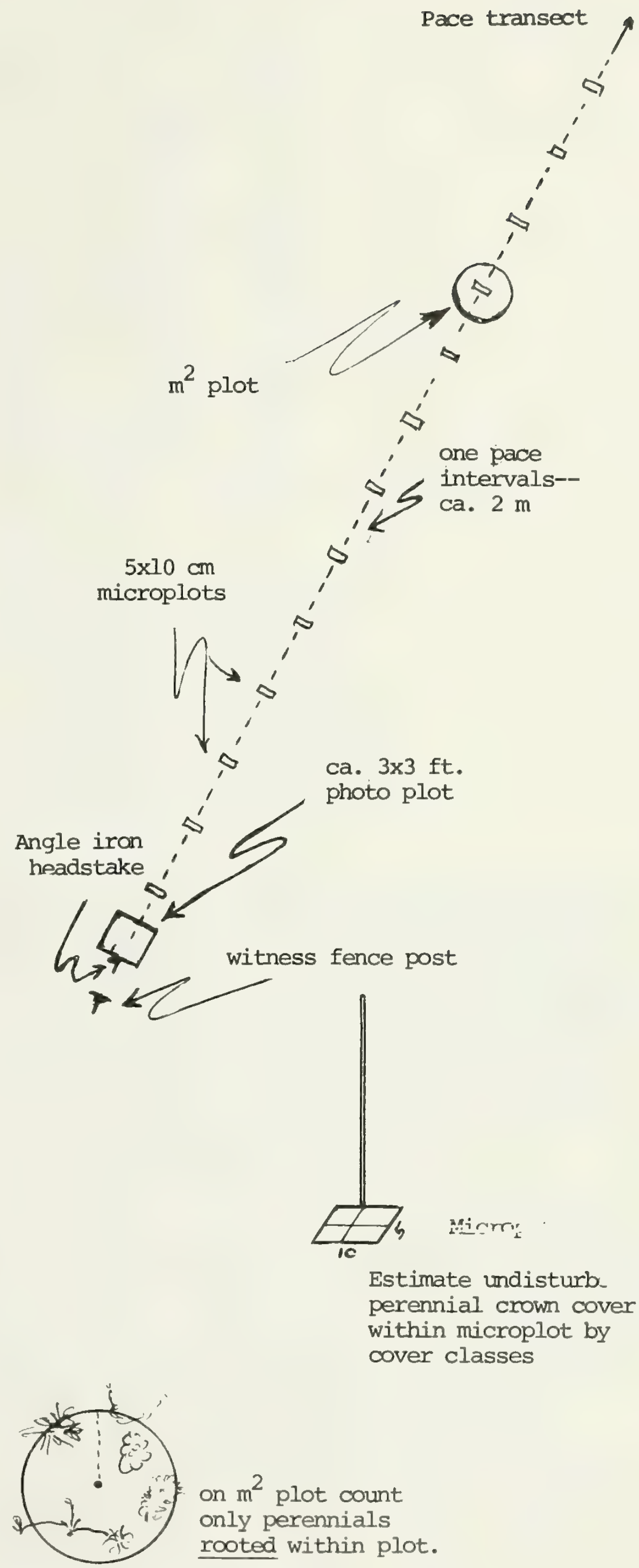

Figure 2.--Plot layout for the CSA transect.

2. At each transect head stake, draw a random number from 0 to 360 corresponding to the transect bearing. Drive an angle iron-stake into the ground 2 m from the location post along the selected transect bearing. The range examiner will begin at the headstake, and read a microplot at every alternate step (approximately 2 m). At each microplot, record living perennial plant cover by species, by the following scale: t = <5%, 1 = 6-15%, 2 = 16-25%, 3 = 26-35%, 4 = 36-45%, 5 = 46-55%, 6 = 56-65%, 7 = 66-75%, 8 = 76-85%, 9 = 86-95%, 10 = 96-100%. The microplot frame is 5 x 10 cm divided into quarters to assist in estimation. Include all shrubs and half-shrubs, but not trees. Estimate and record litter and rocks over 2 cm diameter. Litter is loose plant debris, or standing dead material obviously not of the current year's growth.

Synusae or layers of vegetation will be estimated separately; hence individual microplots may occasionally exceed 100% cover. A total of 100 microplots should be measured per transect.

Centered on each 10th microplot, locate and read a m^2 circular count-list quadrat. All perennial forbs, shrubs, and half-shrubs rooted within the plot will be tallied by species. Count all perennial grasses within the plot. Be especially careful to identify plants as units (for bunchgrasses). Sod grasses, such as western wheatgrass, will be considered as though each discrete culm or culm-group represents a separate plant. In communities where sod grasses are abundant, it may be preferable to use a .5 m^2 circular plot.

When a species is unknown or too fragmentary for identification, mark the species as UNK-3-1 for the first unknown for Transect #3, UNK-3-2 for the second unknown, etc., or use an individual collection number. Collect the plant and preserve for later identification if the specimen is adequate.

3. Take one photo from the headstake looking along the transect line, focusing on an area including the angle iron stake in extreme foreground. A general view photo should then be taken along the transect line; include sky line to assist in orienting the examiner for future retakes. A small slateboard with appropriate information should be set in the foreground of the photograph to identify the transect and date.

Office Procedure

Field sheets are summarized and checked by field crews, then transferred to Fortran Coding sheets (fig. 3). After keypunching they are processed by Program COSAM, developed by the Rocky Mountain Forest and Range Experiment Station at Fort Collins, Colorado. Printout will include plant cover, litter, rock, and bare soil (in percent), absolute cover (percent), density in plants per square meter, and frequency by species, as well as the IV (Importance Value) (fig. 4).

If computer capability is not available, the IV for each species may be computed as:

$$IV_i = \frac{C_i}{\Sigma C} + \frac{D_i}{\Sigma D} + \frac{F_i}{\Sigma F}$$

where IV_i is the Importance Value of the i^{th} species, and C, D, and F are the average cover, density, and frequency for that species. ΣC, ΣD, and ΣF are the sums of cover, density, and frequency for all species in the sample. In our example printout (fig. 4),

$$IV_{Hija} = \frac{4.690}{14.814} + \frac{13.56}{26.57} + \frac{0.59}{2.34} = 1.079$$

After all IV's are calculated, the species are arrayed in order of decreasing IV.

Segregation of sites into arbitrary "condition classes" such as excellent, good, fair, and poor, based on IV, will require more research and a substantial body of knowledge not yet available. However, changes in range health or "condition" will be objectively determined by examining the changes within the array from year to year. If undesirable species become less "important" with time, range condition (whatever its class) is improving; if they become more "important", range condition is deteriorating. The CSA method provides a quick, effective method to measure such change.

Field Test of Procedures

Reproducibility between observers was field tested in the summer of 1979 on a Hilaria jamesii-Sporobolus cryptandrus association near Albuquerque, New Mexico. Seven observers read three transects each, consisting of 100 microplots and 10 macroplots per transect. A steel surveying tape was laid on the ground, and all observers read each transect independently before it was moved, hence there was no relocation error for any of the plots.

Predictably, there was considerable difference among observers for absolute values of cover and density. Cover values by individual observers, for example, ranged from 12.2 to 17.2 percent, with a mean of 14.5--not a very large spread, as field cover measurements go. Total density estimates ranged from 26.6 to 37.5 plants per m^2, with a mean of 33.6. Variation in this statistic was mainly due to the inexperience of some observers in identifying what comprised a "plant unit" in such species as blue grama and alkali sacaton. Variations in the estimates of frequency, on the other hand, were largely due to inability of some of the observers to correctly identify certain grasses and forbs on the

CHARLIE PASE 1979 COSAM DATA
ALLOTMENT 46 SAN YSID
PASTURE- ARMI 10 TRANSECTS
VEGETATION TYPE 1 PLANT COVER 14.814 LITTER 3.068 ROCK .068 BARE 82.052

SPECIES IDENTIFICATION					IMPORTANCE
SPECIES	SCIENTFIC NAME	COVER	DENSITY	FREQUENCY	VALUE
HIJA	HILARIA JAMESII	4.690	13.56	.59	1.079
SPAI	SPOROBOLUS AIROIDES	7.410	6.01	.45	.919
SIHY	SITANION HYSTRIX	.409	2.35	.40	.287
BOGR	BOUTELOUA GRACILIS	.323	2.44	.14	.173
GUSA	GUTIERREZIA SAROTHRAE	.258	.61	.16	.109
ATOB	ATRIPLEX OBOVATA	.902	.06	.08	.097
ORHY	ORYZOPSIS HYMENOIDES	.175	.50	.11	.078
CELA	CERATOIDES LANATA	.330	.12	.08	.061
SOLA	CHAMAESARACHA CORONOPIS	.013	.20	.11	.055
SPDI	SPHAERALCEA DIGITATA	.010	.39	.09	.054
SPCR	SPOROBOLUS CRYPTANDRUS	0.000	.06	.03	.015
BOERI	BOUTELOUA ERIOPODA	.210	0.00	0.00	.014
STNE	STIPA NEOMEXICANA	0.000	.06	.02	.011
AGSM	AGROPYRON SMITHII	.065	.06	.01	.011
ASTR	ASTRAGALUS	0.000	.01	.02	.009
OPCL	OPUNTIA CLAVATA	0.000	.05	.01	.006
PHLO	PHLOX LONGIFOLIA	.020	.02	.01	.006
SCPA	SCHEDONNARDUS PANICULATUS	0.000	.04	.01	.006
2462	CHAMAESARACHA CORONOPIS	0.000	.02	.01	.005
CYFE1	CYMOPTERUS FENDLERI	0.000	.01	.01	.005
	TOTALS	14.814	26.57		3.000
	DIVERSITY		1.49		

Figure 3.--Computer printout of pasture summary with species arrayed by Importance Value. A similar printout is available for individual transects.

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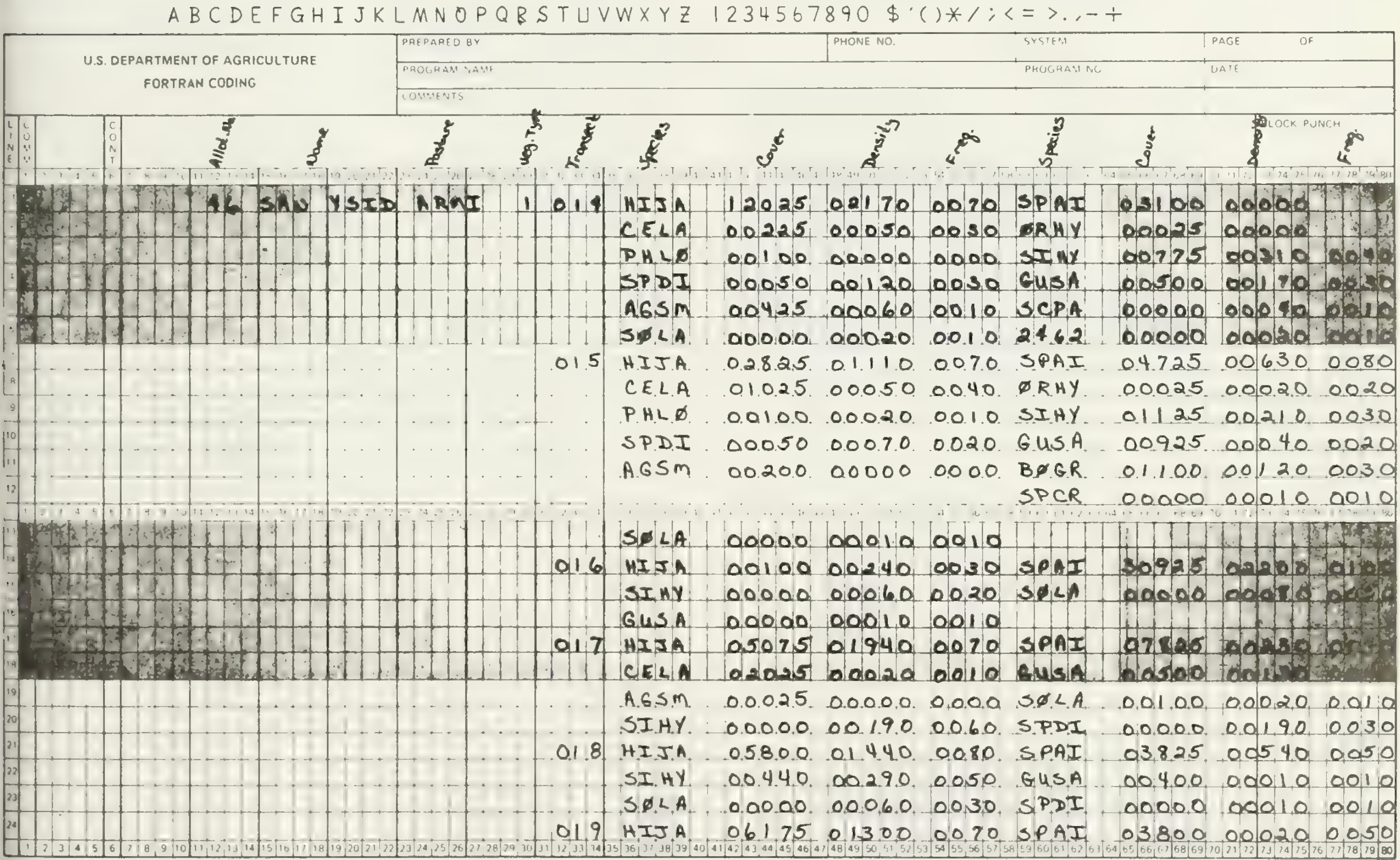

Allot. No.	Name	Pasture	Veg. Type	Transect	Species	Cover	Density	Freq.	Species	Cover	Density	Freq.
46	SAN YSID	ARMI	1	014	HIJA	12025	02170	0070	SPAI	03100	00000	
					CELA	00225	00050	0030	ØRHY	00025	00000	
					PHLØ	00100	00000	0000	SIHY	00775	00310	0040
					SPDI	00050	00120	0030	GUSA	00500	00170	0030
					AGSM	00425	00060	0010	SCPA	00000	00040	0010
					SØLA	00000	00020	0010	2462	00000	00020	0010
				015	HIJA	02825	01110	0070	SPAI	04725	00630	0080
					CELA	01025	00050	0040	ØRHY	00025	00020	0020
					PHLØ	00100	00020	0010	SIHY	01125	00210	0030
					SPDI	00050	00070	0020	GUSA	00925	00040	0020
					AGSM	00200	00000	0000	BØGR	01100	00120	0030
									SPCR	00000	00010	0010
					SØLA	00000	00010	0010				
				016	HIJA	00100	00240	0030	SPAI	[illegible]	[illegible]	[illegible]
					SIHY	00000	00060	0020	SØLA	00000	[illegible]	[illegible]
					GUSA	00000	00010	0010				
				017	HIJA	05075	01940	0070	SPAI	[illegible]	[illegible]	[illegible]
					CELA	02025	00020	0010	GUSA	00500	[illegible]	[illegible]
					AGSM	00025	00000	0000	SØLA	00100	00020	0010
					SIHY	00000	00190	0060	SPDI	00000	00190	0030
				018	HIJA	05800	01440	0080	SPAI	03825	00540	0050
					SIHY	00440	00290	0050	GUSA	00400	00010	0010
					SØLA	00000	00060	0030	SPDI	00000	00010	0010
				019	HIJA	06175	01300	0070	SPAI	03800	00020	0050

Figure 4.--Sample Fortran sheet with input data taken from field transect sheets.

Table 1.--Importance Value comparisons among seven observers for a Hilaria jamesii-Sporobolus cryptandrus association. Comparisons are based on three transects with a total of 300 5 x 10 cm microplots and 30 m^2 macroplots

	Observer								
	1	2	3	4	5	6	7	X	s
Hilaria jamesii	1.122	1.040	1.038	1.030	1.111	1.047	1.042	1.061	0.038
Gutierrezia sarothrae	.807	.787	.762	.840	.705	.756	.787	.778	.043
Sporobolus cryptandrus	.417	.420	.435	.412	.422	.458	.394	.423	.020
Sporobolus airoides	.225	.312	.322	.303	.367	.341	.323	.313	.044
Aristida fendleriana	.110	.117	.112	.115	.137	.112	.149	.122	.015
Haplopappus spinulosus	.080	.082	.067	.073	.064	.079	.080	.075	.007
Sitanion hystrix	.057	.037	.066	.069	.053	.058	.052	.056	.010

basis of vegetative characters alone. Frequency estimates for major vegetation components were quite consistent among observers. For galleta, the most important species, the range was from 0.83 to 0.90, with a mean of 0.86.

Synthesis of the IV using relative values of cover, density, and frequency tended to remove some of the variation among observers, as would be expected if the observers were to estimate consistently, whether high or low. The Importance Values of galleta, for example, ranged from 1.030 to 1.122, with a mean of 1.06 (Table 1). The highest estimate, therefore, was only 5.7% higher than the average, and the lowest estimate, only 2.9% lower than the average for all seven observers. As one descends from "most important" to the "least important" species representing rare or infrequently encountered plants, variation among observers increased. However, all seven observers ranked the most important seven species in the same order, and five of the observers placed the next two species similarly in positions eight and nine. It is important to note here that the eighth-ranked species had an average IV of only 0.038 out of a total stand IV of 3.000, and thus could scarcely be called an important community component at this time. However, these small components of the community may be the most sensitive to change, and cannot be disregarded.

Summary

The Community Structure Analysis (CSA) method appears to be a rapid, reasonably reliable method to describe and analyze semiarid range vegetation. It can be readily learned by technicians and other field personnel. Variation between years due to climatic differences is minimized, as is the bias among observers. The data appear to be highly reproducible.

Field testing of the method on a variety of vegetation types is needed to further assess its applicability.

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RESUMEN

El método CSA puede ser utilizado para estimar el valor relativo de una planta dentro de una comunidad vegetal usando un Valor de Importancia basado en la cubierta vegetativa, la densidad y la frecuencia. Teóricamente, el V.I. se afecta muy poco con las fluctuaciones en la precipitación de año en año. Las pruebas de campo señalan poca diferencia entre los observadores. Un cambio en el V.I. indica que ha habido cambios en las condiciones del campo.

Diagonal Plots for Arid Land Resource Inventories[1]

Kevin R. Dobelbower and Boris Zeide[2]

Abstract.--Square plots layed out by measuring two diagonals and the right angle between them are more efficient for resource inventories than circular plots. The main advantage of diagonal plots is that they allow quick and reliable check of borderling trees.

INTRODUCTION

The low density and heavy branching of woody vegetation in arid zones practically precludes the use of the most efficient inventory technique -point sampling- at least in the traditional form of counting trees in proportion to the basal area of their stems. A possible modification of point sampling -counting in proportion to basal of crowns-would require development of a set of coefficients to convert counts to total and stem biomass. Plot techniques, on the other hand, are readily applicable to arid land resource inventories. In this paper, circular plots -which are currently in favor-will be compared to a much overlooked technique described in 1940 by Dunbar.

Each viable technique offers its own compromise between accuracy and speed. A strong point of circular plots is speed, since a single dimension, the radius, defines the entire perimeter (Kulow 1966, Husch et al. 1972, Loetsch et al. 1973). The perimeter itself is the smallest one for a given area. However, the circular shape of the perimeter makes it difficult to delineate and hence difficult to judge a borderline tree as in or out of the plot without time-consuming distance measurements. Standard circular plot technique (Forbes 1955) calls for the measurement of four equally spaced radii and the distance to each doubtful tree.

To compare the efficiencies of circular and diagonal plot techniques we must know the average number of doubtful trees to be measured per plot. A canvassing of over twenty practiced foresters throughout the United States, combined with our own experience, showed that this number varies greatly with tree density and size, amount of understory and, perhaps most importantly, with the skill of the surveyor. A general consensus was expressed by Carlton M. Newton, Professor of the University of Vermont, who recommends that at least three borderline trees be checked on a typical fifth-acre plot (Newton 1980, personal communication).

Checking borderline trees presents no problem on rectangular plots where boundaries are straight lines between marked corners. A glance from one corner to another tells us immediately whether a tree is "in" or "out". However, the layout of a rectangular plot, particularly the square, is more time-consuming than that of circular plots because measurement of the perimeter and three right angles is generally called for.

Another method of establishing square plots was suggested by Dunbar (1940). We will call it "diagonal plot technique" because it requires measurement of two diagonals, instead of the perimeter, and one right angle between them. Though Dunbar did not present any information regarding the efficiency of his method, and it did not attract the attention of many foresters, the technique seems promising enough to warrant furthur investigation.

METHOD

Testing Procedure

Personnel

Two junior forestry students of Cook College Rutgers University performed the field work. Time measurements were made by a third person who did not participate in regular plot work.

Training

Prior to this study each student had completed a 4-credit Forest Mensuration and 3-credit Forestry

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[1]Paper presented at the Arid Land Resource Inventories Workshop, (La Paz, Mexico, November 30-December 6, 1980).

[2]The authors are, respectively, senior forestry student, Department of Horticulture and Forestry, Cook College, Rutgers University, New Brunswick, N. J. 08903; and Associate Professor of Forestry, Department of Forestry, University of Arkansas at Monticello, Monticello, AR 71655.

Field Practice course. Training for this project consisted of establishment of 15 circular and 15 diagonal practice plots.

Equipment

During preliminary work, a rangefinder and a right angle prism - instruments mentioned in the literature (Lindsey et al. 1958) - were tried and rejected as impractical. The following materials were used for both circular and diagonal plots:

1. One Suunto compass (bearing type preferred over azimuth) for running cruise lines and turning a right angle at the diagonal plot center.

2. A tape (not on a reel) for measuring plot radii and diagonals. A tape of slightly more than the proper length, marked with brightly colored adhesive tape for accurate distance, is preferred.

3. Five flags, each constructed of a quarter inch diameter, 70 inch long fiberglass "whip" with a terminal, brightly colored pennant. These are commonly available, at low cost, where bicycle accessories are sold. Each weighs only 3.5 ounces, is flexible, durable, and easily inserted into the ground. The flags were found to be highly visible, even in dense undergrowth.

4. Two calipers or Biltmore sticks for determining tree diameter.

5. Recording materials.

6. Stakes for plot centers if required for subsequent control.

In addition, in this study a stopwatch was used to measure duration of operations.

Study Area

A mature hardwood forest dominated by <u>Quercus</u> species was chosen for the field testing. It constitutes a part of the Rutgers Ecological Preserve, located in Middlesex County, New Jersey. Mensurational characteristics of the forest were as follows: age 70-95 years, height 23m, diameter 30cm. Undergrowth was heavy and fallen trees and branches were frequent.

Plot Shape and Size

Two types of plots were studied - circular and diagonal. Around each central stake one circular and one diagonal plot was established. An area of one-fifth acre was used for both plot types. In general, to avoid miscounting of trees, the plot size should be chosen to permit an observer at any point near a plot boundary to see the two corner flags delineating that boundary.

Number of Plots

After completion of the training plots, 25 new plots of each type were established. The results were calculated as the average of those 25 plots.

Circular Plot Technique

Setup

1. Layout begins as the cruiser (acting as head chainman) reaches the plot center and places the first flag into the ground. Timing for the study begins at this point. The tally man (rear chainman) pulls the tape tight and locates the second flag.

2. Dragging the tape, the cruiser walks in the direction of the cruise line. The tally man walks to the plot center, where he holds the end of the tape for the second measurement. The cruiser aligns his position with the center and second flags, pulls the tape tight and locates the third flag. The setting of this line need not be exact. The only advantage gained by accurately establishing 180^{o} and 90^{o} angles in this method is that the perimeter is somewhat easier to judge when it is equally divided by the flags.

3. When the third flag is in place, the cruiser returns to the plot center, as the tally man estimates and walks (with the tape) a line perpendicular to the one already surveyed. Distance is taped and the fourth flag is placed.

4. The fifth flag is located as was the second and setup is complete. At this point, the watch is stopped to indicate setup time.

Measurement

The cruiser remains in roughly the outer two thirds of the plot. Trees are visited consecutively in a clockwise direction from the last placed flag. It is the duty of the tally man to record heights as he estimates them, and diameters as the cruiser calls them out.

The tally man may also take diameters of trees in roughly the inner third of the plot; but he must be careful to observe the cruiser's position so that trees are tallied in order.

The most expedient measurement method is for the cruiser to estimate the boundary of each quarter before cruising that area. He may then take up the flags as he approaches them to avoid backtracking. The last placed flag need not be removed until the cruiser finishes his measurement. It may be picked up before he returns to the center. Likewise, the second flag (along the cruise line) may be picked up by the tally man on the way to the next plot. Thus, two flags will remain in place throughout the measurement. Note that the tape is left along the last established line, providing a positive starting and stopping point for the tally. When the cruiser returns to the center, carrying the fifth flag, the watch is stopped showing measurement time.

Borderline Trees

Circular plot method did not include borderline tree checks. The time required for such checks

was determined separately from plot measurement time. An average of 26±0.8 seconds was necessary to check one doubtful tree near the boundary of a fifth-acre plot.

Diagonal Plot Technique

Setup

The diagonal plot is of a square shape, each half diagonal being 20.1 meters, or 66 feet. The method for laying out the four corners is basically the same as establishment of the circular plot radii. Another possible setup precedure which was not employed in our study is to use two strings, tied together in the center, instead of a tape. The knot in the middle is placed over the plot center and the four strands are stretched from the center to the corners. Colored plastic flagging on each strand signifies a corner. The terminal portion of each strand is made of rubber with a hook to catch on the nearby branch of a tree or shrub. The ropes separating the plot into quarters should simplify and increase the accuracy of the tally.

Because incorrect location of corners changes plot area, greater care must be taken in sighting the 180° lines and setting the 90° angles. The straight lines are constructed using compass instead of eye estimation as described for the circular plot.

During step 2 the tally man turns and takes a backsight on the flag he has just left. The first sighting (which is recorded) is subtracted from 90° to obtain the proper bearing for the right angle to be turned. The tally man turns to the new bearing and locates a landmark for a guide. He takes a flag and the tape and proceeds to the new location. The last line is run continuous with the one just established. The turning of the right angle is expedited by tilting the Suunto downward, as if sighting toward the ground; this slows or stops the wheel. Setting the right angle with a compass is not as rapid as an eye estimation but is more precise. When a consistent cruise line is run, the backsight could be eliminated and the same bearing taken each time to locate the 90° angle.

Measurement

The measurement of trees on a diagonal plot is easier than on the circular because the perimeter lines are straight. As a corner is approached, a linear sighting can be made to the next corner; "in" and "out" trees being easily judged. Only twice during the cruise of 25 plots did a tree fall so nearly on the perimeter as to make a determination difficult. In both cases, the tree in question was correctly tallied. Progressive travel from tree to tree and pick-up of flags is the same as for circular plots.

Accuracy

The timer, who did not participate in the tallying operations, watched for possible double counting or skipping of trees within plot boundary. Owing to the extreme care of our field work, no such mistakes were observed. Following the timed setup and measurement of a plot, boundary flags were carefully reset and a check of the tree tally was performed. For circular plot method this control check involved the measurement of additional radii wherever a doubtful tree existed. Diagonal plot corners were remeasured and all central angles adjusted.

Results and Discussion

As a result of this check, it was found that 11 trees were mistakenly included and 4 mistakenly excluded on circular plots. The corresponding numbers on diagonal plots were 5 and 2. In both cases the bias is negligable for it is much less than one tenth of the standard deviation of tree number (Cochran 1977). Therefore, we cannot directly compare the accuracy of the techniques. We might hypothesize, however, that when ordinary, less meticulous tallies are performed the diagonal plots will tend to be more accurate as doubtful trees are much easier to check by that method.

The results of the measurement of 25 circular and 25 diagonal fifth-acre plots are given in table 1. The table contains the arithmetic means and corresponding standard errors of the measurements discussed above.

Table 1.--Amounts of time spent and establishment and measurement of circular and diagonal plots

Measurement	Plot Type: Circular	Plot Type: Diagonal
Number of trees per plot	12.0±0.8	12.2±0.8
Time per plot, seconds		
Setup	92.0±3.5	133.4±4.3
Measurement of trees	167.9±4.9	175.5±4.8
Borderline tree Check (3 trees)	76.8±1.4	0
Total	336.7±6.5	308.9±7.1
Time per tree	28.06	25.24

It is evident that diagonal plots are less time-consuming than circular plots, even though the comparison was made assuming only three borderline trees. This difference in total time, though small, is statistically significant:

$$t = \frac{336.7-308.9}{\sqrt{6.5^2+7.1^2}} = 2.89;\ d.f.=48;\ P(t \geq 2.89)<0.005.$$

However, the main advantage of diagonal plots, in our opinion, is not this, rather modest gain in time.

The advantage is that the design of diagonal plots guarantees a quick and reliable check of all borderline trees. The diagonal technique is less ambiguous in this point, crucial for accuracy, than the circular plot technique. In the latter technique, the number of trees to be checked is uncertain and depends on subjective judgement of a surveyor which may be affected by tiredness, struggle with bugs and stubborn undergrowth.

As a result, diagonal plots offer an attractive solution to the accuracy-speed dilemma: they are both potentially more accurate and actually require less time than circular plots.

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RESUMEN

Los sitios cuadrados que han sido delineados utilizándose la medida de dos diagonales y el ángulo recto entre ellos, resultan más eficientes que los sitios circulares para hacer un inventario de recursos. La ventaja principal de los sitios diagonales es que éstos permiten hacer una verificación rápida y confiable de los árboles marginales.

Double-Frequency Sampling for Inventorying Vegetation on Salt Desert Shrub Ranges[1]

Neil C. Frischknecht[2]

Abstract.--This paper describes a double frequency sampling technique and a calculated distribution index to characterize vegetation on salt-desert shrub ranges. We have used this rapid objective technique to measure changes due to different grazing treatments and to determine baseline data ahead of surface mining as well as success of revegetation following mining.

INTRODUCTION

Two basic sampling techniques for inventorying range vegetation on the ground involve use of fixed plots of selected sizes and shapes and various types of distance measurements or plotless techniques. It is not our purpose here to evaluate the pros and cons of these basic techniques, but to indicate how fixed plot techniques have served our needs for measuring changes in vegetation due to treatments.

Over 30 years ago, we suggested that a circular plot 9.6 ft^2 in area, or some variation of that size, would enable range managers to form a concept so that they could make reasonably accurate estimates of range productivity in pounds per acre (or kilos per hectare) by ocular reconnaissance (Frischknecht and Plummer 1949). Grams on that size plot were converted directly to pounds per acre by merely adding a cipher (0). We agreed with other proponents of the weight estimate method (Pechanec and Pickford 1937) that estimates would allow a broad area to be surveyed in a relatively short time. By the same token, weight estimates would allow more frequent inventories than clipping plots would for a given expenditure of time and money. Although estimates are highly subjective and require training time for standardization among individuals, a double sampling technique (Wilm and others 1944), where a percentage of plots are clipped and estimates adjusted accordingly, ensures greater accuracy of estimates. Herbage weight by species serves two important purposes: it is a measure of site potential, and it is directly related to animal productivity, hence range and ranch economics.

In a subsequent publication, (Frischknecht and Harris 1968), we described use of the same plot frame to sample both herbage production and grass basal area by dividing the hoop into six 1.6 ft^2 segments with cross wires (fig. 1). Its accuracy was dependent upon the examiner being able to visually fit grass basal area into the plot segments. Again, the method was subjective and required time for training. Using that technique, we measured changes in grass basal area due to different intensities and systems of grazing. Like others, we recognized that grass basal area was influenced less by seasonal variations than was herbage weight. Both have importance for evaluating range potential and condition and trend.

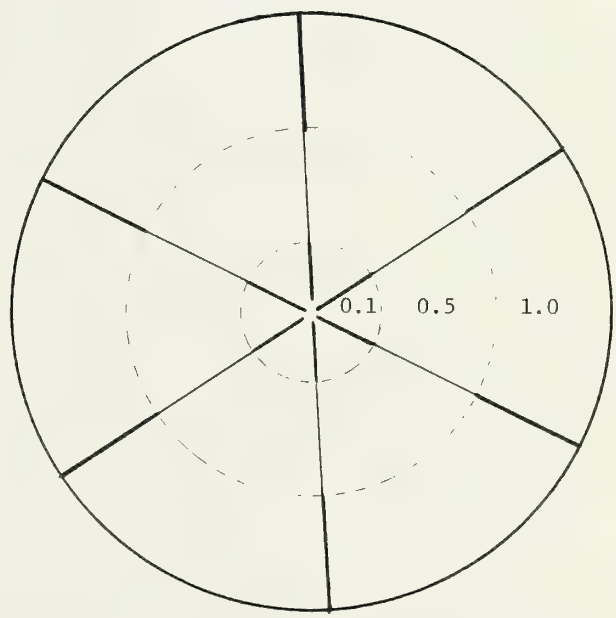

Figure 1.--Diagram showing cross wires on 9.6 ft^2 plot, marked with colored tape corresponding to 0.1, 0.5, and 1.0 ft^2 sampling units to facilitate estimates of grass basal area.

[1]Paper presented at the Arid Land Resource Inventories Workshop, La Paz, Mexico, November 30-December 6, 1980.

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DOUBLE FREQUENCY TECHNIQUE

Most recently we have used a double frequency method to inventory vegetation on salt-desert shrub ranges where annual precipitation averages from 6 to 8 inches (150 to 200 mm). Mere determination of presence or absence of plants within a fixed area is a rapid and objective method for obtaining data about plant communities. Plant cover and density of perennial vegetation are less affected by seasonal variations than plant height and weight. Thus, frequency can be used to evaluate changes in vegetation due to various disturbances other than weather. Although frequency is not an absolute measure of vegetation, such as density, cover, and yield, it reflects certain absolute characteristics of vegetation. It depends in part upon density and in part upon pattern of distribution (Goodall, as cited in West and Baasher 1968).

The technique does not require training nor does it require checking of estimates. Its accuracy depends upon our being able to identify species and to recognize plants. The center of an individual plant or one-half of its basal area must be within a specific quadrat to be counted. Single-stemmed plants require definition as to what constitutes an individual plant. In addition to frequency, plant density and biomass can be obtained rather quickly in one or more subdivisions of the plot we use, depending upon intensity of inventory desired. Thus, frequency alone can be used to characterize plant communities or it can be used to complement data on weight estimates and/or other vegetation parameters.

Because frequency is dependent upon plant density and pattern of distribution, the size of plot used becomes very important. Any plot size will sample some species more adequately than others. After much trial and error, Raunkiaer (one of the earliest advocates of frequency sampling) finally implemented a circular-hoop sampling unit of 1.11 ft^2 (0.1 m^2) (Brown 1954). Curtis and McIntosh (1950) concluded that a quadrat should be one to two times as large as the mean area per individual of the most common species. Thus all randomly distributed species would have quadrat frequency of 63 percent for a quadrat one times the mean area per individual and a frequency of 86 percent for a quadrat two times the mean area per individual. On that basis, Hyder and others (1963) determined that a quadrat 6 to 10 in^2 was appropriate for frequency sampling of the common species in a low sage-Idaho fescue association, and that allocations of 10 to 20 quadrats per transect allowed optimum efficiency. For determining density as well as frequency, ecologists have found that the most accurate measure of density is obtained when the quadrat size is such that percent absence is around 20 percent when plants are distributed at random. Hutchings and Morris (1959) and West and Baasher (1968) determined that Ceratoides lanata, a prominent plant on salt-desert shrub ranges, had random distribution.

Working with mapped plants in the salt-desert shrub types of northwestern Utah, West and Baasher (1968) determined that a rectangular plot that best estimated density and frequency of whitesage (Ceratoides lanata) and Nuttall saltbush (Atriplex nuttallii) had a length 2-1/2 to 2-2/3 times the mean interplant distances. Plot width was one-tenth of the length. These authors concluded that 5 years of protection from grazing was adequate to induce statistically significant differences in distance between individual plants of the same species. Thus, the mean interplant distances for Atriplex were 17.1 cm on unprotected areas and 15.5 cm on protected areas. For Ceratoides lanata, the mean interplant distances were 24.1 cm on unprotected areas and 19.9 cm on protected areas. The decrease in mean interplant distances with protection suggests that plant numbers increased with protection from grazing. Whether the entire change occurred in 1 year of high precipitation or whether there was an annual increment is unknown. As pointed out by these authors, plant numbers and distances between plants tend to vary with the successional status of vegetation. Random distribution is indicative of stable vegetation.

We have used a method that helps to overcome the problem of plot size by simultaneously determining frequency on two sizes of plots, one being one-tenth the size of the other, and calculating a distribution index based on these two evaluations of frequency. To do this, we subdivided a 2-x5-ft (6- x 15-dm) wire frame main plot into ten 1 ft^2 (3 x 3 dm) segments or subplots for sampling vegetation by species (fig. 2). Simply stated, the subplots measure the number of square feet of ground surface that are stocked with plants by species or by the same token, the number of square feet devoid of vegetation or that contain only annuals as compared to perennials. Measuring the square feet of ground surface that possess certain characteristics such as perennial plants, annual plants, cryptogams, and barren soil are absolute measures of ground surface. The distribution of seedlings, litter, and any other characteristics related to range condition and trend can be objectively quantified by this technique simply by defining the parameters and then determining their presence or absence on each of 10 contiguous square foot subplots. This is another way of looking at the ecosystem by focusing attention on the ground surface for the presence or absence of plant and soil characteristics related to range condition and trend.

Figure 2.--Diagram of plot frame used in frequency sampling.

The fact that there are 10 contiguous subdivisions means that percent frequency is obtained directly each time the plot frame is placed on the ground. By using a battery of main plots or transects, we automatically determine frequency on the larger (10 ft^2) (6- x 15-dm) plot as we determine frequency on the smaller plots. Although the number of large plots required per transect will vary depending upon homogeneity of vegetation, our sampling procedures on salt-desert shrub vegetation usually involved transects of 20 such plots. Frequency of the most prominent species on this size plot was usually between 60 and 90 percent on a 20-plot transect. This is within the range for plot size suggested by the investigators previously mentioned. From the two frequencies we have calculated a distribution index (DI) for each species expressed as a decimal as follows:

$$DI = \frac{\%\ \text{frequency per}\ \ 1\ ft^2}{\%\ \text{frequency per}\ 10\ ft^2}$$

The higher the distribution index, which can never be more than one, the greater the concentration of plants within the 10 ft^2 (6- x 15-dm) plot. Both frequency on the larger plot and distribution index, which involves subplots, are important and must be used together to characterize a plant community. One way to do this is to group species frequencies on the main plot into the five size classes proposed by Raunkiaer, which gives a heirarchal ranking for comparing the distribution indices, i.e., class 5 = 81-100 percent, class 4 = 61-80 percent, class 3 = 41-60 percent, class 2 = 21-40 percent, and class 1 = 1-20 percent frequency. A relatively high frequency class for the larger plot reflects wide distribution of a species, whereas a high distribution index reflects a relatively high concentration of plants in areas where the species occurs. Thus, a species might have the same distribution index on two sites, but different frequency classes for main plots. Summing the distribution indices and the main plot frequencies (or the frequency classes) can characterize a plant community, and reflect range condition and/or site potential as described later.

In evaluating range condition and trend, one must be able to recognize the normal or optimum condition when one sees it (Ellison 1949). This can be done by comparing a grazed range with one that has not been grazed or by comparing a deteriorated range with one known to be in good condition. We have used the method in two ways: (1) to determine differences in vegetation on salt-desert shrub ranges resulting from different grazing histories, and (2) to obtain baseline data before simulated surface mining in order to evaluate success of revegetation following treatment.

CHANGES DUE TO GRAZING

Data in table 1 show frequency and distribution index (DI) for five plant species on opposite sides of a fence having different grazing histories for the last 40 years. Both areas were grazed similarly by sheep prior to construction of the fence 40

Table 1.--Plant frequency and distribution index in a Ceratoides lanata-Artemisia spinescens community

	Spring-grazed			Winter-grazed		
	Frequency %			Frequency %		
Species	10 ft	1 ft	DI	10 ft	1 ft	DI
Ceratoides lanata	[1]100.0(5)	71.0	0.71	100.0(5)	59.0	0.59
Artemisia spinescens	15.0(1)	1.5	0.10	90.0(5)	26.5	0.29
Oryzopsis hymenoides	30.0(2)	4.0	0.13	55.0(3)	8.5	0.15
Xanthocephalum sarothrae	5.0(1)	0.5	0.10	35.0(2)	3.5	0.10
Sporobolus cryptandrus	5.0(1)	0.5	0.10	5.0(1)	0.5	0.10
Halogeton glomeratus	10.0(1)	0.5	0.05	5.0(1)	0.5	0.10
TOTAL	165.0(11)	98.0	1.19	290.0(17)	98.5	1.33

[1]Numbers in parentheses are frequency classes of Raunkiaer (see Brown 1954).

years ago. Since that time, the one area has been grazed only in the dormant season (January and February) and only in alternate years, whereas the other area has been grazed into the spring growing season (March and April). The greatest species difference between the two areas in table 1 is reflected in the 90 percent (class 5) frequency of budsage on the winter-grazed area compared to 15 percent (class 1) frequency on the spring-grazed area. Not only is the species more widespread on the winter-grazed area, it is more concentrated where found, as demonstrated by a distribution index of 0.29 on the area compared to 0.10 on the spring-grazed area. Budsage begins growth in early spring, at which time it is highly palatable to sheep and vulnerable to damage from overgrazing (Holmgren and Hutchings 1972). Here is a case where a highly palatable plant has shown increase under the winter grazing regimen over a 40-year period, although it probably remained about the same on the outside area.

Although frequency of whitesage on the main plots is 100 percent (class 5) for both areas, the lower distribution index on the area grazed in winter (0.59) compared to the area grazed in spring (0.71) suggests that budsage has taken up some space formerly occupied by whitesage. On the other hand, both Indian ricegrass and snakeweed showed higher main plot frequency on the winter-grazed area, but little difference in distribution index between the two areas. This indicates that these two species are more widely distributed on the winter-grazed area, but the concentration of plants where they are found remains about the same on the two areas. Both areas are considered to be in good range condition and this is reflected in the relatively low distribution index and low frequency of halogeton, an introduced poisonous annual weed. However, vegetation on the area grazed only during the winter dormant season could be considered indicative of site potential. Totals for main plot frequencies

or classes are much higher on the area grazed only in winter, which indicates that most species are more uniformly distributed than on the spring-grazed area.

Another situation is presented for a whitesage-blacksage community in table 2. The area on one side of the fence has been grazed by sheep only in fall for about 40 years, whereas the area on the other side has been grazed at various times from October into spring. Again the two areas were alike before the dividing fence was built 40 years ago. The relatively high main plot frequency and distribution index of blacksage on the area grazed only in fall suggests that this species has been increased by that treatment, compared to the area grazed fall, winter, and spring. Again, the presence of budsage only on the fall-grazed area is evidence also that this area has not been grazed in spring. Here is a case where the sum of main plot frequencies or classes is the same on the two areas; but two annuals, halogeton and Salsola, make a larger contribution to the total on the area grazed fall, winter, and spring. Again, vegetation on the area grazed only during the fall dormant season would be considered indicative of site potential.

BEFORE AND AFTER MINING

We have used this method also to compare success of vegetation following simulated mining with baseline data on vegetation prior to disturbance. Public Law 95-87 known as the Surface Mining Control and Reclamation Act of 1977 requires successful reclamation of disturbed lands following mining. Section 515 of the act regarding performance standards requires revegetation by a "diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area of land to be affected and capable of self-regeneration and plant succession at least equal in extent of cover to the natural vegetation of the area; except, that introduced species may be used in the revegetation process where desirable and necessary to achieve the approved postmining land use plan...." The operator's responsibility and liability extends for a period of 10 years following seeding in areas where precipitation is 26 inches (65 cm) or less annually.

Table 2.--Plant frequency and distribution index in a Ceratoides lanata-Artemisia nova community

Species	Grazed fall, winter, spring Frequency % 10 ft	1 ft	DI	Grazed fall only Frequency % 10 ft	1 ft	DI
Ceratoides lanata	[1]70.0(4)	32.5	0.46	85.0(5)	31.0	0.36
Artemisia nova	40.0(2)	8.5	0.21	65.0(4)	19.5	0.30
Chrysothamnus stenophyllus	30.0(2)	8.5	0.28	50.0(3)	14.0	0.28
Artemisia spinescens	0.0	0.0	--	5.0(1)	1.5	0.30
Oryzopsis hymenoides	15.0(1)	1.5	0.10	0.0	0.0	--
Sphaeralcea grossulariafolia	5.0(1)	0.5	0.10	0.0	0.0	--
Halogeton glomeratus	45.0(3)	25.0	0.55	10.0(1)	3.5	0.35
Salsola kali tenuifolia	5.0(1)	0.5	0.10	0.0	0.0	--
TOTAL	210.0(14)	77.0	1.52	215.0(14)	69.5	1.59

[1]Numbers in parentheses are frequency classes.

Table 3 shows baseline data in the form of frequency and distribution indices for vegetation on the Emery coal field ahead of simulated mining and also for the revegetated area in the third year following planting. We consider that requirements of the law have been met in that the reclaimed area supports a mixture of native and introduced grasses and shrubs equal or better than the original on the basis of sum of frequencies on the two sizes of plots. Prior to treatment, Hilaria jamesii exhibited the highest frequency and distribution index of any species followed by Atriplex confertifolia and Oryzopsis hymenoides, all native perennials. Hilaria jamesii was not used in the seeding mixture for postmining reclamation because seed was unavailable, but the other two species were both used along with several other species shown in the posttreatment column. Frequency of Oryzopsis was 55 percent both before and following treatment, but the distribution index was slightly higher before treatment. Frequency of Atriplex was 70 percent following reclamation compared to 60 percent before treatment, but, here again, the distribution index was higher before treatment. Native Ceratoides lanata was not found on the area prior to treatment, but shows good adaptation on the reclaimed site. Highest frequencies on the reclaimed site were expressed by Agropyron cristatum and Elymus junceus, both showing 100 percent frequency with a distribution index of 0.42 and 0.26, respectively.

Other Advantages

The 2- x 5-ft (6-x 15-dm) plot frame possesses other desirable characteristics: (1) it approximates in size the 9.6 ft^2 plot that has been used in many studies for making weight estimates directly in pounds per acre. In fact if a 6- x 15-dm frame was used, the 90 dm^2 area thus encompassed is equivalent to 9.68 ft^2 and biomass can be obtained rather quickly on one or more of the 10 subplots by clipping or estimating, depending upon the intensity of inventory desired; (2) the frame in metric units can be used to sample permanently established meter-square quadrats by marking the edges of the frame in 1-dm segments and sampling one-half m^2 at a time; (3) the rectangular frame satisfies recommendations for using rectangular plots (Bormann, as cited in Cain and Castro 1959); (4) the frame folds in the middle, is easily carried in the field, and can be used as a measuring device to determine height and width of woody plant crowns or to measure canopy area.

Table 3.--Frequency and distribution index before simulated mining and 3 years after

Species	Before treatment Frequency % 10 ft	1 ft	D.I.	3 years after treatment Frequency % 10 ft	1 ft	D.I.
Oryzopsis hymenoides	[1]55.0(3)	14.0	0.25	55.0(3)	10.5	0.19
Atriplex confertifolia	60.0(3)	37.5	0.62	70.0(4)	14.0	0.20
Hilaria jamesii	90.0(5)	60.0	0.68	--	--	--
Sitanion hystrix	5.0(1)	0.5	0.10	--	--	--
Artemisia spinescens	5.0(1)	0.5	0.10	--	--	--
Eriogonum corymbosum	5.0(1)	0.5	0.10	--	--	--
Sphaeralcea grossulariafolia	5.0(1)	0.5	0.10	--	--	--
Halogeton glomeratus	25.0(2)	10.0	0.40	--	--	--
Salsola kali tenuifolia	5.0(1)	0.5	0.10	--	--	--
Agropyron riparium	--	--	--	70.0(4)	16.0	0.23
Agropyron cristatum	--	--	--	100.0(5)	41.5	0.42
Elymus junceus	--	--	--	100.0(5)	26.5	0.26
Ceratoides lanata	--	--	--	65.0(4)	14.0	0.29
Atriplex canescens	--	--	--	15.0(1)	1.0	0.07
Ephedra nevadensis	--	--	--	10.0(1)	2.0	0.20
TOTAL	255.0(18)	124.0	2.54	485.0(27)	125.5	1.86

[1]Numbers in parentheses are frequency classes.

SUMMARY AND CONCLUSIONS

We have used a double frequency technique and a calculated distribution index to characterize vegetation on salt-desert shrub ranges. The technique involves determining plant frequency on two sizes of plots, the smaller (subplot) being one-tenth the size of the larger (main) plot. To do this, we subdivided a 2- x 5-foot (6- x 15-dm) rectangular wire frame into 10 subplots, each 1 ft^2 (3 - x 3-dm) in area. Using a transect of main plots, we calculated a distribution index by dividing percent frequency on the smaller plot by percent frequency on the larger plot. Without directly determining density, the distribution index is related to density and distribution of plants. It provides information on plant concentrations in areas where plants are found.

Simply, stated, the subplots measure the number of square feet (3- x 3-dm) of ground surface that are stocked with plants or by the same token, the number of square feet (3- x 3-dm) that are devoid of plants. The distribution of plants, seedlings, litter, and any other vegetation and/or soil characteristic related to range condition and trend of range condition can be objectively quantified by the technique simply by defining the parameters and then determining their presence or absence on each of the 10 contiguous subplots. Although plant frequency is not considered an absolute measure of vegetation, measuring the square feet (3- x 3-dm) of ground surface that possess certain vegetative or soil characteristics is an absolute measure. The technique is objective, rapid, and requires neither training nor the checking of estimates. We have used it to measure changes due to different grazing treatments, to evaluate site potential, and to obtain baseline data ahead of surface mining, as well as success of revegetation following mining. We are still working to perfect this technique.

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TOMA DE MUESTRA DE DOBLE FRECUENCIA PARA ESTABLECER UN ENVENTARIO DE LA VEGETACION EN LAS ZONAS DE ARBUSTOS DE UN DESIERTO SALDO

SUMARIO Y CONCLUSIONES

Hemos usado una técnica de doble frecuencia y un indice de distribución calculada para caracterizar la vegetación de las zonas de arbustos en un desierto salado. La técnica tiene que ver con la determinación de la frecuencia de vegetación en parcelas de dos tamoños diferentes. La parcela más pequeña o parcela secundaria es la décima parte de la parcela más grande o parcela principal. Para llevar a cabo esto, tomamos una armazón rectangular de alambre de 6 x 15 dm. y la subdividimos en 10 cuadros secundarios de 3 x 3 dm. cada uno. Haciendo un corte transversal de las parcelas principales calculamos un índice de distribución al dividir el porcentaje de frecuencia de las parcelas más grandes por el porcentaje de frecuencia de las parcelas menores. Sin determinar directamente la densidad, el índice de distribución está relacionado con la densidad y la distribución de las plantas. Provee información sobre la concentración de las plantas en zonas donde existe vegetación.

Para decirlo de otra manera, las parcelas secundarias miden el número de superficies de 3 x 3 dm. que cuentan con vegetación, y por ende, el número de zonas de 3 x 3 dm. que carecen de vegetación. Esta técnica puede cuantificar objetivamente la distribución de plantas establecidas, plantas en desarrollo, humus, y cualquier otra clase de vegetación, así como la caracteristica del terreno relacionada con la condición del campo y sus variantes. Tan sólo se necesita definir los parámetros y luego determinar si se dan o no en cada una de las 10 parcelas secundarias contiguas. La frecuencia con que se dan las plantas no se considera una medición absoluta de vegetación, pero el medir las zonas de superficie de 3 x 3 dm. que poseen ciertas características vegetativas sí es una medición absoluta. La técnica es objetiva, rápida y no requiere ni entrenamiento ni comprobación de estimaciones. Nosotros hemos empleado esta técnica para medir las variantes que han resultado como consecuencia de diferentes tratamientos de pastoreo. También la hemos usado para evaluar el potencial de un sitio y para obtener información previa al minado de superficie, así como el resurgimiento de la vegetación después de haberse minado. Hoy día, seguimos tratando de perfeccionar esta técnica.

The mK^2 Generality[1]

Thomas W. Beers[2]

The proportion of area covered by aggregated objects can be estimated simply by mK^2, making use of the concepts of horizontal point sampling orginally described by Bitterlich. Diverse examples from the literature are given and an application to arid land inventories is suggested.

INTRODUCTION

Few will quarrel with the notion that the variable probability sampling concepts introduced to the forestry world by Bitterlich (1948) and Grosenbaugh (1952) have had a profound and lasting effect on forest inventory. The universal acceptance of horizontal point sampling (one form of variable probability sampling) verifies the significance of Bitterlich's original ideas. Yet, it is sometimes useful to re-examine "old ideas" and re-organize or re-categorize certain related concepts. In so doing, one may roll back the frontiers of knowledge just a bit, or at least make a few clearings in the forest of the unknown to make the way easier for those to follow. The purpose of this paper, then, is to report on one such study -- the organization of some old concepts which leads to--the mK^2 generality.

FORMULA DERIVATION

If we assume an inventory is to take place to determine the total area "covered" by an aggregate of objects (e.g., trees, shrubs, pulpwood sticks), the estimation formula can be derived making use of the Horvitz-Thompson estimator (Ware, 1978) as follows: assume the estimate is to be made from one point and the principles of horizontal point sampling are to be used, then

$$\hat{Y} = a_1 \frac{1}{P_1} + a_2 \frac{1}{P_2} + \ldots + a_m \frac{1}{P_m}$$

where

$\hat{Y}$ = an estimate of the total area covered by the aggregated objects,

a_i = individual object area in the same units as $\hat{Y}$

$= \Pi r_i^2$, if r_i = object radius,

P_i = probability of selecting the i^{th} object,

and m = number of objects qualifying for the sample at that one location. But it can be shown geometrically that the probability, P_i, is found by

$$P_i = \frac{(\text{plot area})_i}{\text{total "tract" area}}$$

If we assume the units to be feet, then

$$P_i = \frac{\Pi R_i^2/43560}{A} = \frac{\Pi R_i^2}{43560\ A}$$

where

A = "tract" area in acres,

and R_i = radius of the plot associated with the i^{th} object, in sq. ft. From the fundamentals of horizontal point sampling, the ratio of object radius to plot radius is constant,

therefore

$$K = \frac{r_i}{R_i},$$

leading to

$$R_i = \frac{r_i}{K}.$$

Now, P_i becomes

$$P_i = \frac{\Pi \frac{r_i^2}{K^2}}{43560\ A} = \frac{\Pi\ r_i^2}{43560\ K^2 A}$$

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[1]Paper presented at Arid Land Resource Inventories. La Paz, Mexico. Nov. 30-Dec. 6, 1980.

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and

$$\hat{Y} = \Pi r_1^2 \frac{43560 K^2 A}{\Pi r_1^2} + \cdots + \Pi r_m^2 \frac{43560 K^2 A}{\Pi r_m^2}$$

$$= m \, 43560 \, A \, K^2$$

Dividing both sides of the equation by the total "tract" area in sq. ft. (43560 A): $\frac{\hat{Y}}{43560 A} = m K^2$.

Thus:

$$\left.\begin{array}{l}\text{proportion of area}\\ \text{covered by the}\\ \text{aggregated objects}\end{array}\right\} = m K^2$$

where,

m = count of the qualifying objects

K = proportionality constant

$$= \frac{r_i}{R_i}$$

The constant K is related to the angle, Θ, "generated" by the point sampling angle gauge by the relation: $K = \sin \frac{\Theta}{2}$.

It is now a matter of picking a value of K^2, and developing the gauge required to generate Θ to provide a "convenient" technique.

EXAMPLES FROM THE LITERATURE

1. Shrub Density.

Describing a procedure to estimate the proportion (or percentage) of land area covered by shrub clumps, Cooper (1957) chose $K^2 = .01$, leading to $K = .1$ and $\Theta = 2 \arcsin .1 = 11.48^\circ$.

Thus

shrub density = m (.01),

and each qualifying shrub clump represents 1 percent of the area covered. In the study Cooper also noted that a 2 percent contribution led to a more desirable sample size; therefore $K^2 = .02$, $K = .1414$, $\Theta = 16.26^\circ$. In field use then, one needs an angle gauge which generates an angle of 16.26° so that each qualifying shrub contributes 2 percent to the estimate of shrub density at one location.

2. Crown Density.

Working with tree crowns, Bitterlich (1961) chose $K^2 = .1$ leading to $K = .3162$ and $\Theta = 2 \arcsin .3162 = 36.87^\circ$.

Thus

crown density = m(.1),

and each qualifying crown represents 10 percent of total crown coverage. The gauge used must generate an angle of 36.87° to achieve this convenient contribution of each tree crown.

3. Bunchgrass Density.

Using the same approach as Cooper (example 1), Hyder and Sneva (1960) describe another sampling scheme which may prove useful for arid-land inventories. They studied the estimation of relative density of various species of "bunchgrass", by choosing $K^2 = .01$ leading to an angle, Θ, of 11.48°. Each tallied clump of bunch grass therefore contributed 1 percent to the estimate of percentage coverage of the land at the one point.

4. Pulpwood Density.

Bitterlich (1957) provides another imaginative example in his technique proposed to estimate the proportion of area on the "face" of a stack of pulpwood which is made up of solid wood. He chose $K^2 = .04$, leading to $K = .2$ and to $\Theta = 23.07^\circ$.

Thus

$$\left.\begin{array}{c}\text{proportion of solid wood}\\ \text{to}\\ \text{wood plus air space}\end{array}\right\} = m\,(.04),$$

and each qualifying pulpwood stick represents 4 percent of the stack's total face area. Bitterlich chose $K^2 = .04$ so that when one calculates an average proportion from 4 locations:

$$\text{average proportion} = \frac{m_1 + m_2 + m_3 + m_4}{4} (.04)$$

$$= \sum_{i=1}^{4} m_i \; (.01).$$

Therefore, when one uses four sample locations each qualifying stick contributes 1 percent to the overall estimate. Additionally, it should be noted that this average proportion is also the factor to convert the stack volume from wood + air space to solid wood, assuming the pulpsticks are of equal length.

5. Basal Area Density.

A final example completes the cycle of historical development. Bitterlich (1948) in his orginal work on what came to be known as horizontal point sampling (Grosenbaugh, 1958), could have chosen (he used metric units) $K^2 = \frac{1}{4}(\frac{1}{33})^2 = .0002296$, leading to $K = \frac{1}{66} = .0151515...$, and $\Theta = 1.74^\circ = 104.18'$.

Thus

$$\left.\begin{array}{l}\text{proportion of tree} \\ \text{basal area on each} \\ \text{acre of land}\end{array}\right\} = m\left[\frac{1}{4}\left(\frac{1}{33}\right)^2\right] = m\left(\frac{1}{4356}\right).$$

Multiplying both sides of the equation by 43560 to convert the proportion to actual sq. ft. of basal area on the acre of land

$$\text{basal area per acre} = m \left(\frac{1}{4356}\right) 43560$$

$$= m\ (10)$$

We can recognize the 10 in this formula to be the basal area factor, the per acre basal area contribution of each tree, uniquely associated with a gauge angle of 104.18 minutes.

ARID-LAND APPLICATION?

It is frequently advantageous to re-examine and re-develop "old" approaches because in the process, new applications and insights may be generated. Such a possibility is described in the following paragraphs.

Recalling example 2, the estimation of crown density, it is apparent from the description of the technique by Loetsch, et. al. (1973) that application on the ground may encounter practical problems such as caused by crown overlap and the difficulty of actually determining the crown periphery. However, for arid-land application where vegetation "crowns" may not severely overlap and where aerial photographs can be used, "crown closure" or crown density may be easily determined by the technique. (Loetsch, et. al., 1973, cite Klier, 1969, as having done this.)

If we again assume that appropriate aerial photos are to be used, a sampling method developed by Wenk (1965) and described by Loetsch, et. al. (1973), may also be used advantageously to estimate the average crown diameter of the vegetation from a count of the qualifying objects (trees, clumps, etc). That is, no crown measurements need be taken since Wenk's method samples with probability proportional to object diameter (as opposed to diameter squared for examples 1 through 5).

Since the method of Wenk also makes use of a fixed-size plot, it would be very simple to estimate the number of objects per unit area from counts only, from the plots imposed on the photographs.

Thus, if we were to develop, by regression techniques, a prediction equation relating the desired expression of vegetation biomass, to the independent variables "crown" density, average or sum of "crown" diameters and number of "crowns", it would be feasible to estimate the amount of biomass present without making any measurements on the photographs. Making use of the techniques just described, a functional relation could be derived so that only the count of qualifying sample individuals (or clumps) appear in the prediction equation.

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RESUMEN

La proporción de área cubierta por un conjunto de objetos se puede estimar sencillamente utilizando mK^2, haciendo uso del concepto de muestreo de punto al horizontal descrito originalmente por Bitterlich. Se discuten aquí diversos ejemplos de la literatura, y se sugiere una aplicación para inventarios de tierras áridas.

Aquatic Inventories — The BLM Oregon Experience[1]

Neil B. Armantrout[2]

Abstract.--The Bureau of Land Management in Oregon is developing an integrated habitat inventory system, based on individual habitat components and habitat requirements of individual fish species. The system can be used in data processing, and allows for analysis and impact prediction. It is fully integratable with other resource inventories.

INTRODUCTION

Aquatic and associated riparian habitats occupy 2 to 5% of the land base in arid regions. While limited in quantity, the aquatic and riparian habitats are of major importance to wildlife. In one report (Thomas, 1979), it was stated that 80% of the terrestrial species, in addition to the aquatic and amphibious species, utilize the aquatic and riparian habitats of the western United States. Because of the presence of water and abundant vegetation, these same aquatic and riparian areas are also the most used and most modified by man. While the aquatic and riparian systems are closely integrated, they do represent two separate but overlapping types of habitats. This paper will concentrate on the aquatic habitat.

The basic aquatic system is the result of interaction of geomorphology, climate, soils and vegetation. Interaction of the various influences, through time, produced the current drainage patterns and habitat conditions. Each aquatic system has a range of conditions, with the limits of the range being established by the interaction of the determining influences. Changes in the aquatic system can occur, but the type and degree of change is controlled by the overall potential of the aquatic system.

The existing conditions at any point in the system are an integration of a variety of influences upstream from that point. Unlike many other resources, such as soils, vegetation, timber or minerals, the aquatic system may be profoundly influenced by distant actions. Changes in water quality, quantity, annual cycles, etc., result from upstream activities. For example, a major dam or water diversion alters the entire aquatic ecosystem downstream. With changes in the physical conditions, the suitability for habitat for fish and other organisms is also altered. As a result, land management activities throughout a basin can, in large measure, determine the amount and quality of aquatic habitat in arid regions.

The Bureau of Land Management, as a major land management agency in the arid areas of the western United States, has sought to improve its system of inventories and planning to better manage its resources. During the last year and a half, biologists from the Oregon State Office and the eleven districts in Oregon and Washington, have been reviewing the current Bureau aquatic inventory systems. The following comments summarize the results of that review.

INVENTORY NEEDS

Inventories are conducted to provide information about the quality and quantity of resources present and their condition. The actual need for the information, such as for research, planning or utilization, will determine the type of information collected in an inventory and the form in which it is summarized.

The inventory of aquatic habitat should include information describing the entire basin of the aquatic system. While management activities for which information is needed may be very site-specific, the influences of conditions or activities elsewhere in the basin can have a major impact on possible options at any site-specific location. Because of the need to consider the aquatic system within the framework of the overall basin ecosystem, there is considerable overlap with other resource inventories, and information from the other resource inventories can be used to supplement the information obtained through the aquatic inventories.

[1]Paper presented at the Arid Land Resource Inventories Workshop, La Paz, Mexico, November 30 to December 6, 1980.

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While the actual informational needs should determine the type and extent of an inventory, there are several questions that should be considered:

1. What is the basic resource? The basic resource is the stream course or lake basin, the landform, water supply and associated flora and fauna as it existed in the pristine condition.

2. What changes have occurred? Few aquatic systems in arid regions remain unchanged. A variety of human activities have contributed to alteration of the basic resource. An inventory would consider how the aquatic system and its associated ecosystem have changed and what has brought about the change.

3. What is the current condition? The condition refers to the current quantity and quality of the habitat and the associated species compared to the potential for that particular aquatic system. Condition, as here used, is a description of existing habitat and biotic components and a comparison of their status with the potential. While the potential is usually the natural situation found in the pristine condition, it can also be the potential as expressed in terms of management goals for an area.

4. What are the trends? No system is static, since there is constant flux in the physical and biological elements. Some of these are short term deviations, reflecting seasonal and annual changes in use, water supply, or climatic conditions. The trend represents the average, long-term direction in condition; whether the amount and quality of the habitat, with associated biota, are improving, becoming less favorable or remaining in an overall static condition.

5. What activities and management practices are occurring? This would identify past and current activities in a basin, both at the point of the inventory and elsewhere in the system as it influences the point of the inventory.

6. Are there items of special interest? Governmental agencies often establish categories of wildlife and resource areas that are to be given special attention. These include, for example, endangered and threatened species, wilderness areas, areas of critical environmental concern, national parks, refuges and research natural areas. The inventory procedures should provide for the identification and evaluation of habitats and populations that are included in such special use areas or which would qualify for such consideration.

7. What is needed to maintain or improve the resource? The basic needs of the habitat should be identified during the inventory. The actual needs may be the result of basin-wide or site-specific problems.

BASIC AQUATIC SYSTEM

Initial inventory efforts should be to describe the potential and current aquatic system on a basin-wide, ecosystem approach. This is often general in nature, and addresses the broad availability of water and its movements, the landform type, water quality and general habitat type. (Figure 1). Where a stream or landform classification system is operational, the classification for a particular water body is often an adequate indicator of the basic aquatic system.

In arid areas, the demands for water and vegetation have resulted in almost universal modification of the pristine habitat. Changes are often drastic, sometimest to the point that the aquatic system ceases to exist as a habitat type and is little more than a production and storage facility for human use. The initial inventory efforts should include consideration of the modifications that have occurred in the basin, and the impacts on the aquatic system.

The combination of the basic habitat description and the modifications in the basin produces the current habitat type and condition (Figure 2). The description of this basic current habitat type and condition then becomes the framework for conducting the site specific inventories, and for development of subsequent management options for either a site-specific or basin-wide plan.

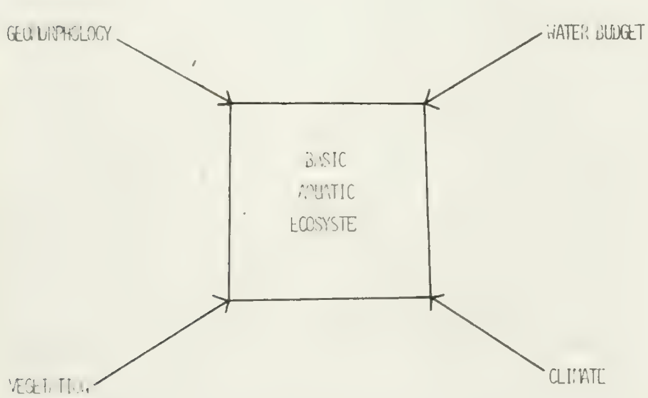

FIGURE 1. FACTORS DETERMINING THE BASIC AQUATIC ECOSYSTEM

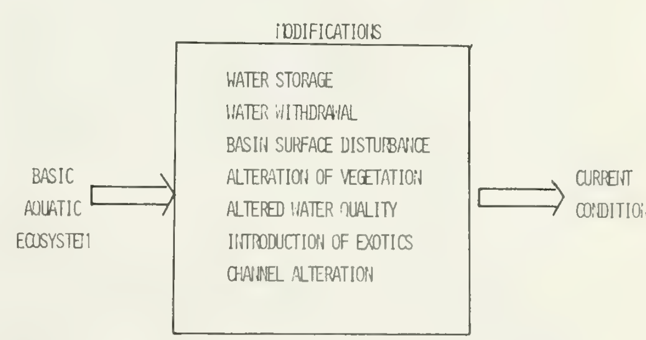

FIGURE 2. HUMAN ACTIVITIES ALTERING THE AQUATIC SYSTEM TO PRODUCE THE CURRENT CONDITION.

SITE-SPECIFIC INVENTORIES

The actual site specific inventory effort will depend upon the purpose of the inventory, and can range from a cursory examination to detailed studies and research. Several approaches can be used, with inventories based on the proposed use of the resource, on specific species, on selected habitat components, or on interactions with other resources.

Our approach with the Bureau of Land Management in Oregon has been to base the inventories on the habitat elements needed by fish. All animals have similar basic habitat requirements. The presence or absence of the necessary habitat components determines the species distribution and abundance. Some of the basic habitat needs for fish are summarized in Table 1:

TABLE 1. BASIC HABITAT NEEDS FOR FISH

Reproduction: free access for migratory movements and adequate habitat for reproduction, including substrate of the proper type and quality, adequate water quality, and normal annual sensory cues to promote maturation.

Nursery and Rearing Areas: Areas with adequate protection from currents and from predators; an adequate food supply of the proper size and type.

Cover: Escape and resting areas; havens or refuge areas for inclement periods of climate and flow conditions.

Food: An adequate supply of food for each phase of the life cycle, and for each season of the year.

Water: Water in sufficient quantity and quality for maintenance of the species at all phases of the life cycle.

The expression of individual species needs differs, but the same basic needs remain consistent among fishes. For example, salmonids need cool, clear water, with clean gravel for spawning. Centrachids, on the other hand, can live in warm water, and can spawn in muddy-silty areas. The inventory is developed to measure elements of the aquatic system that can be used to indicate suitability of the habitat for individual species by habitat component. The inventory can be conducted so that the habitat needs of a selected species are considered, or the inventory may be broad-based, with the suitability for a particular species being indicated by evaluation of the information obtained.

A variety of habitat elements may be included in an inventory. In a listing of elements we compiled, over 300 were included. However, many of these are needed for specific management problems and are not part of a habitat inventory. Instead of trying to cover all possible habitat elements, we selected a series of elements that can provide us with the most information for effort expended. Major groups of habitat elements selected for inventories are summarized in Table 2.

TABLE 2. HABITAT INVENTORY ELEMENTS

1. Stream Character
   a. Channel width, depth and stability
   b. Pool availability and quality
   c. Substrate type and stability
   d. Gradient and currents
   e. Stream structure
   f. Flow patterns

2. Lake Basin Character
   a. Width to depth patterns
   b. Shoreline development
   c. Stratification and mixing patterns

3. Geomorphology
   a. Landform of basin
   b. Form and slope of adjacent lands
   c. Sinuosity of channels
   d. Elevation

4. Vegetation
   a. Upslope vegetative type, cover, condition and composition
   b. Riparian vegetation type, composition, cover, shading, width and height, and current condition
   c. Aquatic vegetation, major types and amounts

5. Water Quality
   a. Temperature of air and water, including diurnal and seasonal cycles
   b. Oxygen
   c. Erosion and sedimentation
   d. Salts
   e. Nutrients
   f. Heavy metals and other chemical factors

6. Biota
   a. Fish species composition, abundance and distribution
   b. Macroinvertebrate diversity, species composition and biomass
   c. Other animals present

7. Current Management
   a. Current water and land management priorities
   b. Fish population management
   c. Recreational or other direct uses
   d. Water withdrawals
   e. Water storage, including hydropower
   f. Special interest species or habitat areas

8. Habitat Management Opportunities
   a. Erosion areas; location, extent and cause
   b. Access and migration blocks
   c. Factors limiting habitat availability or suitability
   d. Habitat expansion and improvement opportunities

The inventory provides documentation of the actual habitat conditions. Food supply is indicated

by the availability of productive substrate and nutrients, by the macroinvertebrate and fish populations, and by the general level of riparian and aquatic vegetation. Cover is influenced by the quantity and quality of stream structure, the quantity and quality of pools, and the general stream character. Similar evaluations for specific habitat components for fish can be made from the individual inventory elements.

In addition to the basic fish habitat needs, information is gathered during the inventory that contributes to the description of the general condition of the habitat, the management of fishes and of adjoining lands, and the general limitations in the aquatic habitat. Also taken during the inventory is site-specific information on problems which may be causing localized degradation, or which are contributing to the overall loss in habitat elsewhere in the aquatic system.

Information may be gathered in a number of ways. For our inventories, we usually make measurements on short sections or reaches, then summarize the values over a larger section of the habitat. The most common procedure is to use 110 meter and 440 meter sections for inventories on smaller streams, and up to 1-2 kilometer sections on the largest streams. The procedure has two advantages. First, it allows for more exact location of specific habitat types and specific habitat problems. Secondly, it is easier to characterize a shorter, more uniform section than a longer section of habitat. The summary for the entire inventory reach then gives a composite picture of the reach as a whole as well as demonstrating variability that exists throughout the reach.

Four methods are used in making measurements, with variable reliability. The actual method used for measuring individual elements depends upon the system of inventory being used, the level of detail desired and the resources available for conducting the inventory. The four general methods are:

1. Gross Ocular: In the gross ocular method, no measurements are actually made. Instead, the individual doing the inventory uses a visual estimate of the availability of the individual inventory elements. The observations may be done on foot, from a vehicle, aircraft or boat. Specific problem areas or items of interest are noted and are located accurately; some of these may be given careful examination or closer measurement if necessary to develop adequate management options.

2. Transect Method: The transect method, as used by BLM, is a refinement of the gross ocular method. An ocular estimate is used for most of the survey. At intervals, representative sample sites or stations are selected. A transect is run across the stream, or, in a lake, profiles of the water column taken, with accurate measurements of the individual inventory elements. The transect measurements are then used as an accurate data base for referencing estimates of the elements for the rest of the inventory taken by ocular methods.

3. Random Measurements: When it is difficult to conduct inventories over the full range of a basin or basin portion, a subsample may be inventoried and the information extrapolated over the whole basin. The inventory sections actually sampled are measured in detail. If the selection of the inventory sections is properly conducted, using known amounts of habitat, the information gathered can be valid when extrapolated to the entire habitat area.

4. Remote Sensing: Two types of remote sensing are being used for aquatic inventories, satellite imagery and aerial photographs. The major difference between the two is scale. With the satellite imagery, the work can be only on a gross level because of the lack of detail. It can be used quite successfully for showing overall ecosystem patterns, including vegetative distribution, erosion areas, topographical problems, channel characteristics, channel stability and concentration areas of human activity. Many of the satellites provide imagery on a regular schedule, permitting observations of seasonal changes, and by comparing images over a period of time, trends.

Aerial photography can accomplish many of the same things as the satellite imagery. However, because of its much finer scale, it allows for more detailed analysis. Stream structures, gradient bottom composition, channel character, shading, and other aspects can be read off the aerial photographs. More detailed and finer descriptions may be made of site-specific opportunities. A fairly good physical description can be made of the aquatic habitat from aerial photographs. As with satellite imagery, seasonal and annual changes and trends can be followed from a series of aerial photographs.

EVALUATION

The inventory information provides a data base for evaluating the current condition of the habitat. By comparison with the potential for the habitat, it is possible to provide a general evaluation of condition. Analysis of specific habitat components permits identification of specific problems and opportunities.

Several methods of evaluation have been proposed by BLM and other agencies. A simple method for providing a general evaluation was developed by the Riparian Subcommittee of the Oregon/Washington Interagency Wildlife Committee (1979). It requires only a general knowledge of conditions, but can be used also with more detail inventories. The method relies on comparison of current conditions in three habitat components; shading, stream sedimentation and bank stability. Generalized curves, summarized from the literature, were used for the comparisons (figures 3,4,5). While the curves are for trout, the three basic components are important to aquatic habitat for all freshwater species. A biologist or other resource manager could use the curves to compare the conditions found in the habitat being considered against the values shown by the curves and readily see how the habitat compares with the potential.

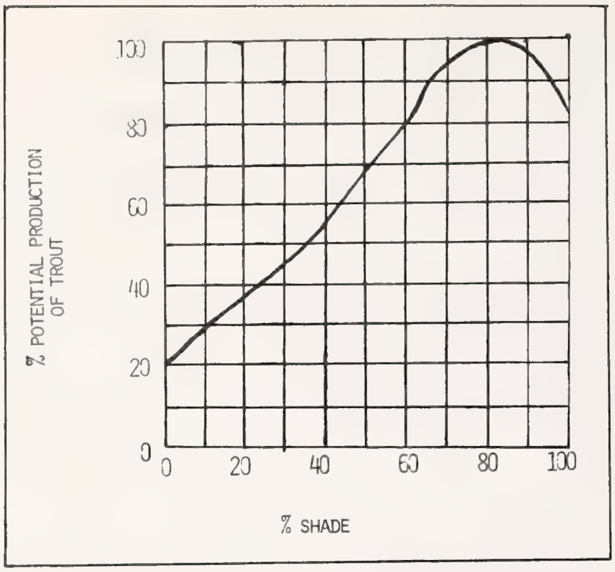

FIGURE 3. TROUT PRODUCTION IN RELATION TO PERCENT OF STREAM WATER SURFACE SHADED

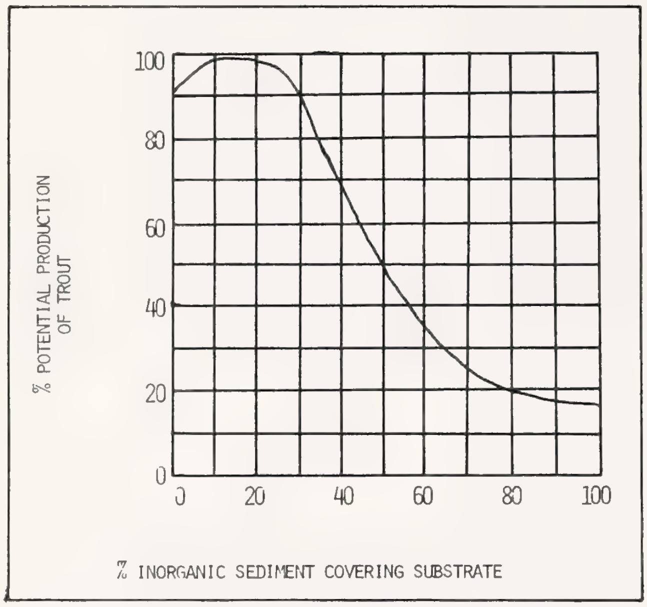

FIGURE 5. TROUT PRODUCTION IN RELATION TO PERCENT OF SUBSTRATE COVERED BY INORGANIC SEDIMENT

A more detailed approach is currently being tested by biologists in Oregon and Washington BLM offices. Under this approach the various habitat components are compared against an optimal habitat condition, and a numerical rating obtained. Since the format is based on specific fish habitat needs, high ratings in one area would indicate good conditions for that habitat component, while low ratings in other components would demonstrate where limiting factors occur. The components used in the rating are summarized in Table 3.

Several problems arose in trying to develop an evaluation procedure, with two being the most troublesome. The first problem is the different conditions in different size streams. Small, upland streams,

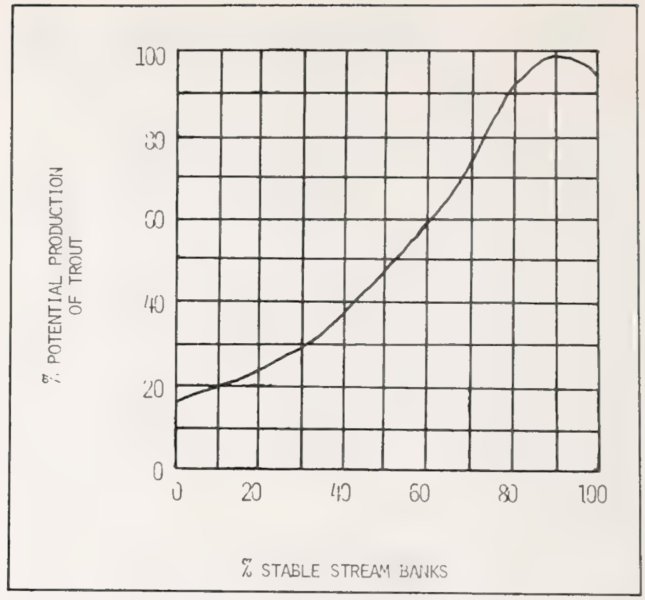

FIGURE 4. TROUT PRODUCTION IN RELATION TO PERCENT OF STABLE STREAM BANKS.

for example, have different problems from large, low-lying streams. While the evaluation considers the same factors for all streams, the relative values of the individual components to different sizes of streams is not considered.

The second major problem is the use of an optimal condition as the comparison for condition. The geomorphic, climatic and vegetative conditions determine the range of potential for a given aquatic system. It may be that the range for a given system would not include conditions that would rate excellent in an optimal system. As a result, some habitats, which may be in a nearly pristine condition for any given habitat area, may rate low when compared to the optimal conditions but which may be excellent for the given aquatic system inventoried.

Neither of these problems seriously limit the usefulness of evaluations. A long as a given system is used consistently as a basis of comparison, the results will be comparable from inventory to invento

TABLE 3. EVAUATION ELEMENTS

1. Flow Patterns: seasonal and annual flow cycles, ranges in flow, and flooding patterns.

2. Temperature Range: Range of normal and extreme temperatures; amount and duration of ice formation.

3. Bank Stability: Degree of bank stability, amoun and size of erosion areas, and presence of bank stabilizing material.

4. Riparian Diversity and Cover: Amount of shading bank cover, diversity of riparian vegetatio and amount of woody vegetation in riparian area.

5. Pool Quality and Quantity: Percentage of the channel as pool, with the general quality of the pool based on size and depth.

6. Spawning Area: Amount of spawning habitat present to the total aquatic habitat, and the condition of the spawning habitat.

7. Rearing Areas: Availability and quality of nursery and rearing areas.

8. Bottom Material: The general type of substrate, with emphasis on rocky material providing stability and a substrate for benthic organisms.

9. Riffle/Rapids: Amount of the stream channel characterized as flowing water.

10. Gradient: Channel gradient, from 0 to over 12%.

11. Dissolved and Suspended Material: Expressed as turbidity or total suspended solids; total dissolved solids or conductivity. Values are for normal flows.

12. Channel Stability: Channel stability, amount and degree of scouring and deposition, adequacy of the channel for usual expected flows.

13. Stream Structure Diversity: Amount, type, and stability of stream structure, and the degree and stability of habitat diversity.

MANAGEMENT OPTIONS AND IMPACT PREDICTION

Inventory information has value only as it is used to better manage a resource. The information obtained in the field can document the habitat available and the current condition of habitat. It can show what fish species are present, and can indicate the use of the fish resource by man. It can also show what changes have taken place in the resource, and what influence man has had upon the resource. The information obtained is the basis for making management recommendations. Habitat recommendations are based on the need to provide the habitat for the selected fish species on the basis of their habitat needs. Fish population management recommendations must consider not only the demands upon the resource, but also the habitat present and its capability to sustain the fish populations. In most cases, recommendations for management are a direct outgrowth of the inventory and evaluation process.

The relationship among habitat elements, fish needs and overall ecosystem interactions provides a method for predicting impacts resulting from changes in the management of the aquatic resource. If the changes in management of the resource or adjoining lands will result in changes in the various habitat elements, then changes can be expected in the fish population distribution, species composition and abundance. The first step is to establish what changes will take place in the specific habitat components in the aquatic system. Then, using the relationships developed from the inventories, it is possible to predict what changes will be expected in the fish populations.

SUMMARY

Aquatic and riparian habitats are some of the most important and most limited of habitats in arid regions. Because of the demand for water and vegetation, no other resource base is less altered. As a result of agricultural, domestic, industrial and other uses, the water based resources have declined or been lost in arid regions of the world as populations have grown and economics expanded.

The Bureau of Land Management, a land management agency with extensive responsibilities in arid regions of the western United States, has been developing an integrated habitat inventory and evaluation system for aquatic habitats. The system is based on a fish habitat needs, and is developed within a basin-wide-ecosystem approach. The inventories look at specific habitat components, such as cover, reproduction, food, rearing areas, and water quality. Based on the needs of individual species, the inventory and evaluation can indicate limiting factors and management opportunities. The needs can be expressed not only in terms of a general problem but also on a site-specifc or component-specific basis.

The inventory and evaluation can be interfaced with other resources. As a result, it is possible to use the system for prediction of impacts, and to indicate results of changes in management of the aquatic system and of other resources on adjacent lands. The system can be used with an automated data storage, retrieval and analysis.

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INVENTARIOS ACUATICO: LA EXPERIENCIA

de BLM de Oregon

Neil B. Armantrout

Sumario

Las habitaciones acuaticos y riberenos son unas de las mas importanes y muy limitadas en rejiones secas. Por razon de exigencia de agua y vegetacion, ningen otro base derecursos es menos alterable. Por el resultado de agricola, industria y otros usos, los recursos de agua se an declinado or perdido en las rejiones secas por el mundo, cuanto la population crece or la economia expande. El "Bureau of Land Management," una agencia para el manejor de trreno publicos de los Estados Unidos, con responsabilidades extensivas en rejiones secas del occidentente de los Estados Unidos, han estado desarrollando un inventorio de habitaciones integrantes y una evalucion para habitaciones aduaticos. El sistma se basada en necessidades de pez, y es desarrollada dentro una vasta immensa y con aproche ecologico. Los enventarios investigan especificas componentes de habitaciones, como cobertizone, reproduccion, alimento, areas para crearse y calidad de agua. Basamiento en las pecesidades de especies individuales, el enventario y evaluaccion pueden ser entremedio o entreacto con otros recursos. Con resulto es posible de utilisar or usar el sistma para predicar miento de los impactos, y para indicar resultados de cambieos en el manejo del sistma acuaticos y de otros recursos de terrenos adyacentes. El sistma puede ser utalicado con un sistma automata de datos almacenados, para recuperacion de datos y anatisis.

Tećnicas para Muestrear y Medir la Producción de Goma de Mezquite[1]

Ileana Espejel[2]

Resúmen.--Se experimentaron diversos cortes en árboles de mezquite (Prosopis laevigata)en Tehuacán, Puebla que permitieron cuantificar la goma producida en un año. La producción de cada árbol es muy variable, posiblemente se deba al genotipo de cada individuo. Se proponen investigaciones para aprovechar este recurso.

INTRODUCCION

Las zonas áridas y semiáridas del país son consideradas las regiones más pobres económicamente y por ésta razón es necesario buscar otros recursos naturales para plantearlos como alternativa y así apoyar la economía campesina, que por lo general tiene muchas deficiencias.

Una de las especies más abundantes en las regiones áridas de México es el mezquite (Prosopis); su distribución es muy amplia y muchas veces es el elemento dominante de la vegetación.

Entre otras cosas los mezquites producen una goma que tiene características semejantes a la goma arábiga, utilizada ampliamente en la industria y que en México se importa involucrando un alto costo. Por estas razones se ha planteado la sustitución de la goma arábiga por la que exuda el mezquite.

Se han realizado varios estudios sobre la composición química de la goma de mezquite (Forbes,R., 1895; Anderson,E.and L.Sands, 1926; Anderson, E. and L. Otis, 1930; White, E.V., 1946-1948; Aspinall, G.O. and C.C. Whitehead, 1970) y sobre los usos que le han dado algunos grupos indígenas en América y Asia (Bell, W.H. and E.F. Castetter, 1937; Signoret, J., 1970; Felger, R. S., 1977; Konda, R., 1978)sin embargo no se había realizado ningún estudio sobre la cantidad de goma producida por el mezquite ni se investigado su potencial de explotación.

OBJETIVO

A causa de lo anterior se planteó una investigación con el objetivo principal de cuantificar la goma exudada por árboles de Prosopis laevigata en Tehuacán, Puebla experimentando diversos cortes durante un año (Febrero de 1979 a Febrero de 1980).

METODOLOGIA

Se experimentaron cuatro tipos de cortes que son :

1) Descortezamientos, que consisten en desprender delgadas capas de corteza de un metro de largo y diez centímetros de ancho(fig. 1).

2) Cortes Diagonales, realizados con un hacha cortando un rectángulo de diez centímetros de largo y dos centímetros de ancho. Se desprendía totalmente la corteza(fig. 2)

3) Cortes con machete, que consisten en incidir el machete con fuerza al tronco o rama del árbol, levantando un poco la corteza y dejando que cubra un poco al leño(fig. 3).

4) Tirar Ramas(fig. 4).

Figura 1.-- Uno de los cortes realizados para obtener goma. Los descortezamientos los realizan en Africa para obtener goma arábiga de varias especies de Acacia. Se realizaron tanto en ramas como en el tronco.

[1] Trabajo presentado en el Seminario de Trabajo "Inventarios de Recursos de Tierras Aridas: Desarrollo de Métodos Eficientes en Costos". La Paz, B. C. México. Nov. 30 a Dic. 6, 1980.

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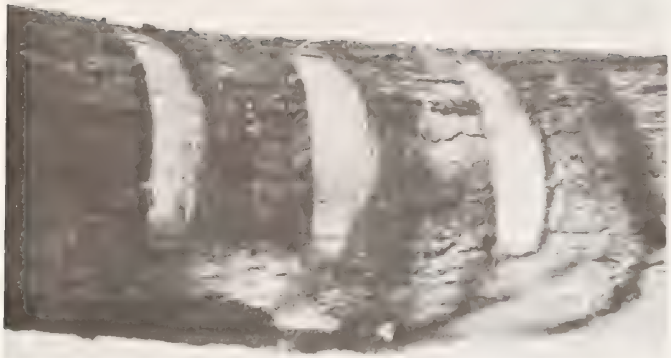

Figura 2.-- Los cortes diagonales se realizaron siguiendo el patrón de cortes para obtener chicle, después se modificó haciendo sólo tres diagonales por árbol.

Figura 3.-- Los cortes con machete fueron hechos por recomendación de los campesinos del lugar, quienes decían que sólo así salía goma.

Figura 4.-- Se tiraron ramas para saber de qué tejido de la madera se exudaba la goma, además de ser uno de los cortes más frecuentes y realizados por los campesinos del lugar.

Primero se les dejó exudar goma durante cuarenta días escogiendo aquellos cortes que habían producido mayor cantidad para después experimentarlos en dos poblaciones distintas, una en terrenos con cultivos de maíz de temporal y otra de riego. Los cortes con mayor productividad resultaron ser los cortes diagonales y los cortes con machete.

Los cortes se hicieron en Febrero de 1979, a cuarenta árboles de ambas poblaciones.

Como tercer experimento se realizaron los dos cortes a tres de los árboles en meses alternados (Febrero, Abril, Junio, Agosto, Octubre y Diciembre) durante un año.

La goma al salir se endurece y es fácil desprenderla con un cuchillo . Se recogía los primeros días de cada mes, guardándola en bolsas de plástico.

Después la goma se limpiaba , secaba y pesaba.

RESULTADOS

Los mejores cortes, por ser los más productivos son los cortes diagonales y los cortes con machete. Los mezquites exudan goma a través de los cortes durante tres o seis meses después de haberlos realizado.

En la segunda parte del experimento no se detectaron diferencias significativas entre la producción de goma a través de los cortes diagonales o de los cortes con machete. El patrón de producción es muy similar en las dos zonas de trabajo, donde Marzo en el mes más productivo(fig. 5).

Los cortes progresivos realizados durante el año produjeron goma en cantidades muy variables y por esto los resultados son también muy complejos.

No hubo forma de establecer un patrón general de comportamiento debido a la alta varianza que hay en la producción de goma entre los individuos.

Por ejemplo dos árboles con características semejantes como son altura de 17.19 y 12.75 m y diámetro a la altura del pecho de 4.57 y 4. 92 cm respectivamente y además compartiendo el mismo ambiente, es decir los dos árboles estan en cultivos de riego) muestran la siguiente variabilidad en cuanto a la producción de goma(tabla 1).

Tabla 1.-- Producción de goma (gramos) de dos árboles de los terrenos de cultivo de riego.

No. de árbol	Mes de realización del corte						Total
	Feb	Abr	Jun	Ago	Oct	Dic	
9	1.9	12.8	7.9	25.2	3.2	2.1	53.70
10	3.6	1.7	5.8	11.1	19.6	3.0	44.80

No se encontró relación alguna entre el diámetro a la altura del árbol y la producción de goma pues algunos árboles de fuste angosto producían

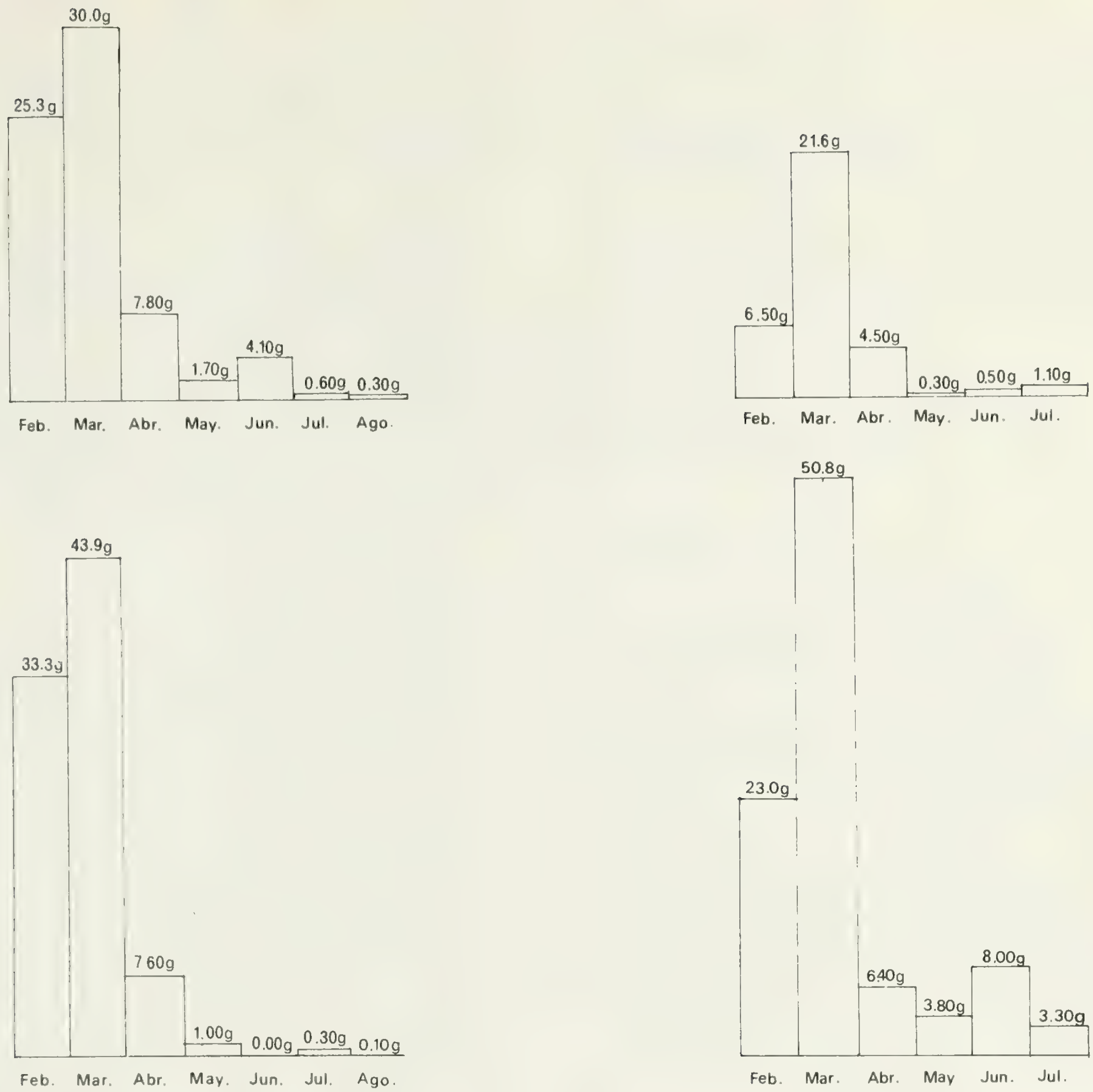

Figura 5.-- Gráficas donde se muestra la producción de gomade la segunda parte del experimento. Aquí se ve que el mes más productivo es marzo, que corresponde a la época seca de Tehuacán, Puebla.

más goma que otros de fuste ancho. Por ejemplo, un árbol de 45.00 cm de DAP produjo durante una año 120.60 g de goma mientars que otro de 88.20 cm de DAP produjo únicamente 32.40 g de goma.

Tampoco se encontró relación entre el clima y la producción ya que cada tipo de corte y cada árbol tuvieron diferentes meses de mayor producción, algunos correspondían con la época de floración o la de fructificación, otros con la época de lluvias, otros con la época seca, etc.

DISCUSION Y CONCLUSIONES

Los dos cortes que producen mayores cantidades de goma son iguales en cuanto a su productividad, pero el corte con machete es más fácil realizarlo y por esta razón se recomienda para futuras experiencias.

En la segunda parte del experimento el número de árboles muestreado fué suficiente como para generalizar y establecer un mes promedio de mayor producción. Sin embargo y de cualquier forma la varianza de la producción entre los individuos es muy grande.

En el tercer experimento el número de árboles no fué suficiente para generalizar y otra vez la variabilidad en la producción de goma entre los individuos resultó muy grande. Con respecto a ésto se piensa que la producción de goma depende del genotipo de cada individuo y no de factores ambientales o externos.

Parece ser que esta variabilidad en la producción también sucede en Acacia senegal (goma arábiga) (Howes, F.N.; 1949; NAS, 1979), por lo que se plantea investigar la fisiología de la producción de goma en las especies productoras de ella, para que así sea posible controlar dicha producción.

Con los resultados obtenidos se llegó a la conclusión de que la cantidad de goma producida por los mezquites puede incrementar, de cierta manera, el ingreso familiar, sin invertir mucho tiempo y dinero, pues tanto la realización de los cortes como la recolección de la goma,es muy sencilla. Además en muchos casos las poblaciones de Prosopis ya existen y no es necesario hacer más inversiones.

De las plantas útiles que existen en México pocas pueden aprovecharse al máximo; Prosopis además de exudar una goma potencialmente útil, ofrece al campesino la posibilidad de explotarlo como recurso maderable, alimenticio o en la producción de miel.

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SUMMARY

Arid lands are considered as the poorest regions of Mexico, for this reason it is necessary to search more natural resources that can be an alternative to help deficient arid land peasant economy.

One of the most abundant and widely distributed species in Mexican arid lands is the mesquite (Prosopis spp.)which produce a gum that is very important since its chemical composition resembles that of arabic gum which is extensively used in ndustry. In Mexico arabic gum is imported with very high costs.

The chemical composition and the uses of the mesquite gum in America and Asia are well known. However, there are no studies about its production.

The main objetive of this investigation was the cuantification of the exudated gum of Prosopis laevigata trees in Tehuacan, Puebla. For this purpose four different cuts were experimented on some trees during one year:

a) The bark stripped,
b) Diagonal cuts,
c) "Machete" cuts and
d) The removal of entire branches.

As the diagonal and"machete" cuts were the most productive we repited them in February 1979 on 40 trees of two different populations. One in seasonal maize crops and the other in irrigated ones.The gum was collected every month during 1979.

Other additional experiments consisted on cutting trees in alternate months through the same year (February, April, June, August, October, and December).

When the gum exudes, it becomes hard and is easy to remove with a knife. The gum was collected in plastic bags. Finally it was cleaned and weighed.

Our field observations showed, in this year, that the cuts exuded gum for three or six months only, that there were apparently no significative differences between diagonal and "machete" cuts gum production, and finally, that March was the most productive month.

The progressive cuts produced very variable gum quantities that conduced to complex interpretations. It was impossible to establish a general gum production behavior. We did not find any relation between tree diameter, climate, phenology and gum production.

We recommend for future experiences the "machete" cuts, since they produce large cuantities of gum and are easier to make.

It should be sampled al least ten, or better more individuals, since this may allow minimal generalizations.

Individual variability in gum production seems to be very high, this was observed in the third part of the experience.

This variability in gum production also happens in Acacia senegal the tree producer of arabic gum.

There is a need of studies on gum production physiology, on how to control it, especially for the people who lives in arid lands.

The mesquite is one of the most useful plants in Mexico since it also offers the possibility of obtaining wood, food, honey and of course, gum.

The Role of Optical Dendrometers in Tree Volume and Growth Measurements[1]

David R. Bower[2]

Abstract.--This paper describes some common dendrometry applications including development of standard and local tree volume equations, and accumulating information on tree taper and growth. Some of the problems associated with field dendrometry, and with tree volume estimation are discussed, as are some alternative volume estimation procedures.

INTRODUCTION

Optical dendrometers provide an efficient method of gathering data for development of standard and local tree volume equations and for accumulating information on tree taper and growth. On the other hand, there are a number of problems associated with field dendrometry which should be considered when planning the tree measurement phase of a research study, a timber cruise, or a forest inventory.

The objectives of this paper are to describe the opportunities and methodologies for field dendrometry and to develop the mensurational aspects of tree and stand volume estimation. In addition, tree volumes compiled from Barr and Stroud dendrometer data will be compared to volumes from felled tree data.

General background and theory of dendrometry has been described by Grosenbaugh (1963).

APPLICATIONS

Develop Standard Volume Tables

Standard volume tables can be developed from measurements taken with a Barr and Stroud optical dendrometer, Wensel (1971). The dendrometer method of data acquisition is more rapid than measurement of felled or climbed trees and is non-destructive. Since measurements are made optically outside the bark, the tree bole must be visible and reliable bark thickness estimators are needed to obtain accurate inside-bark volumes.

A study by the author will be used to illustrate development of a standard volume equation using data taken with a Barr and Stroud, Model FP15, dendrometer. Measurements were made at two locations in Eastern Oregon, on 50 lodgepole pine trees, ranging from 2 to 18 inches in diameter at breast height. The field measurements were completed in two days and a similar amount of time was needed to accumulate tree volumes using Grosenbaugh's (1964) STX program and for fitting a tree volume regression. The tree volume regression was used to accumulate plot volumes from diameter and height measurements. Later the tree volume regression was tested on 40 other felled and sectioned trees from the same general area. As compared to the felled trees, the dendrometer based volume equation overestimated inside-bark volume by only 3 percent, and part of the difference was due to inaccurate bark thickness conversions.

Check Existing Volume Tables

Dendrometer based volume tables can be used to check existing volume tables, Hazard and Berger (1972). Existing standard volume tables may be based on data from a different geographic location than the population of interest. A small sample of trees, with a representative range of diameters and heights, can be measured by dendrometer, volumes accumulated, and comparisons made with published tables (Freese 1960, 1964). In some cases, the accuracy of the published tables may be adequate, and no further sampling is required. In other cases, as in Hazard and Berger's study, results may show a need for improved standard volume equations.

Construct Local Volume Equations

Local volume equations are based on a small "local" sample of diameters and heights. Normally,

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a standard volume equation is used to calculate tree volume from diameter and height and then tree volume is related to some function of diameter. Using dendrometry, tree volume can be accumulated directly, thus by passing the standard volume equation. However, some form of local volume estimator is still required. In 3-P sampling, (Grosenbaugh 1964, 1965, 1967a, 1967b, Mesavage 1965, 1967a, 1967b, Space 1974) an estimator commonly used is a relationship between measured volume and an ocular estimate of volume. Many other estimators of volume are possible. Considering the relationship of volume to a function of diameter, Bower (1972) describes 12 estimators derived from two models, three statistical weights and both conditioned and unconditioned relationships. The applications for local volume equations include research plot volume summaries, cruise plot volume summaries and inventory or survey plot volume summaries. The plot itself may be either fixed area or a variable plot or point sample.

Measurement of Growth

Dendrometers provide an opportunity to measure upper stem growth response following stand treatments, such as fertilization or thinning, Bower (1973). If stand treatments change the shape of a tree, a standard volume equation based on data from an untreated population may provide biased estimates of treatment response. In addition, errors in total height estimation are more critical in volume estimation via standard volume equation than by direct measurement by dendrometer. Depending on cost and time factors, dendrometers may provide efficient estimates of growth for continuous forest inventory plots, but the alternative of measuring more trees, in a specified period of time, by conventional volume table procedures should be carefully evaluated.

FIELD MEASUREMENTS

The following observations regarding field measurements were made by the author from experiences in measuring trees in both western and southern forests of the United States, with both the Barr and Stroud dendrometer and the Spiegel relaskop.

Weather conditions are very important in field dendrometry. Field dendrometry is nearly impossible in rainy weather unless some type of cover is available. Even a light drizzle tends to fog up lenses and slow down the measurement process. Dark days are also a problem, particularly in dense stands, where background trees tend to merge together with the subject tree. On very bright days, the dendrometer measurement position should be selected so that bright sunlight is behind the observor.

Stand density is very important also in optical dendrometry. With the Barr and Stroud dendrometer, the observer must be at least 36 feet away from the tree. The author found that in young dense stands of Douglas-fir (age 25, site II), it was impossible to measure individual trees in unthinned plots. Crown density and crown ratio are important factors, also. In dense crowned species, all bole measurements must be confined to the lower stem. The impact on volume estimation of confining measurements to the lower bole depends on tree size and crown ratio. The effect of partial bole measurement on volume estimation was studied by the author using felled tree measurements on 16 Douglas-fir trees ranging from 60 to 160 feet in height. If measurements were made to 1/2 of the total height, and the top was assumed to be a cone, then total tree cubic foot volume was underestimated by 3.2 percent. However, if measurements were made up to 2/3 the total tree height, then volume was underestimated by only 0.7 percent.

Other factors affecting accuracy of field measurements include background trees and intervening brush. Background trees can be a serious problem on dark days. Instrument location should be selected to avoid problems with background trees wherever possible. On lower bole measurements, a white tablet can be placed behind the measurement tree to improve contrast and remove the problem of distinguishing between background and measurement trees. To avoid problems with brush, it is better to make dendrometer measurements when the hardwood leaves are off. Brush or intervening trees may become a problem over a period of time in remeasurement studies. Some brush clearing may be required.

Selection of measurement position also depends on number of trees visible from the instrument setup. In some cases several trees can be measured from one instrument location. If trees are to be remeasured for growth, the instrument location should be monumented, height of instrument measured, and distance and bearing to measurement trees recorded. At time of remeasurement, dendrometer measurements can be taken from the same instrument location, with the same height of instrument, and at same inclinometer settings (in the case of the Barr and Stroud).

It is usually easiest to measure trees from the uphill side in steep topography. It should be noted that each tree is being calipered from only one aspect and some variation in estimated volume occurs due to trees being out-of-round.

Measurements should be taken more frequently where taper is changing rapidly and less frequently elsewhere.

MENSURATIONAL CONSIDERATIONS

Tree Volume Estimation

The number and location of diameter measurements to be made on a tree depend on tree shape or taper, the algorithm for section volume accumulation, and on desired accuracy. Some computer programs, such as STX, use a single algorithm for

all sections. A single algorithm, whether expressing a convex, conic or concave shape, is adequate if measurement interval is small (Grosenbaugh 1966). Given more widely spaced measurements, a neoloidic formula can be used at the tree base to express the concave shape, a parabolic formula further up the tree where shape is convex and a conic formula at the top. An algorithm can be set up to change the type of computing formula depending on rate of taper (Arney 1968). Bower (1972) developed a general taper relationship that varies the section volume algorithm dependent on measured taper. By comparing short and long vertical measurement intervals and by using the general taper function, Bower (1972) concluded that the subneiloid was the most accurate "single" algorithm for tree volume summation. This is primarily due to the substantial taper (concave shape) which occurs at the tree base, a problem dealt with by Bruce (1970), using a regression approach.

Bower (1972) also found that increasing the vertical measurement interval from 2 feet to 4 feet, for a sample of ponderosa pine trees, caused an overestimate in volume of only 2.6 percent. On the other hand, data by Young (1967) showed that increasing the measurement interval from 8 feet to 16 feet in fir and hemlock increased the overestimate by paraboloid formulae from 3 to 10 percent.

The level of accuracy for an individual diameter measurement probably is not of great importance for most volume estimation purposes but becomes more critical if changes in form due to stand treatments are being appraised (Groman and Berg, Bower 1973).

Bark Thickness Estimation

No matter how precise the outside bark diameter measurements, successful estimation of inside bark volume for individual trees via dendrometry depends on accurate measurements of bark thickness and on accurate models to forecast inside bark diameters from outside bark measurements.

Johnson (1966) developed upper stem bark factors based on 540 Douglas-fir trees. The six basic independent variables were (1) distance up the stem from the ground to the point of measurement, (2) age, (3) diameter at breast height outside bark, (4) total tree height, (5) diameter outside bark at the point of measurement, and (6) a bark factor at the stump. Alternative models were presented for the cases where total height and age are not available.

Mesavage (1969b) tested the three bark options of Grosenbaugh's (1964) STX program, on southern pine. Mesavage found that option 2, in which the ratio DIB/DOB is projected hyperbolically, with constants QUAN=1 and DENO=2, was most accurate for southern pine.

Bower (1973) tested both Floyd Johnson's regression equation and Grosenbaugh's hyperbolic function (option 2) on 16 Douglas-fir trees, with range in height from 60 to 160 feet. Grosenbaugh's hyperbolic function (with QUAN=1, DENO=2) led to a 5.8 percent underestimate of total cubic-foot volume inside bark. The same function with QUAN=.3, DENO=1.3 led to a 2.8 percent underestimate of volume. Floyd Johnson's regression equation led to a 3.9 percent underestimate.

The above tests indicate that more flexibility is required in bark thickness functions. This flexibility may be provided by the generalization of Grosenbaugh's option 2 model as described by Brickell (1970).

Improvements may also be needed in the bark measurement process itself (Mesavage 1969c). Improper use of a standard bark gauge may lead to errors in measurement of bark thickness at breast height.

Stand Volume Estimation

Advantages gained from accurate tree volume measurement by dendrometer may be lost when volume relationships are extended to a stand basis unless accurate stand volume estimators are used. After comparing 12 local volume equations, Bower (1972) concluded that conditioned estimators such as ratio of means, mean of ratios and tariff procedures tend to underestimate stand volume. Apparently, the problem occurs through a loss of generality in the conditioning process. An unweighted and weighted second degree parabola, volume on dbh and dbh^2, with weight inverse to dbh^2, were consistently the most accurate stand volume estimators. However, these estimators sometimes estimate negative volumes for small trees.

SOME FIELD TRIALS

A number of studies have compared various dendrometers with the Barr and Stroud or have compared the Barr and Stroud diameter measurements with caliper measurements (Grosenbaugh 1963). A few studies have compared tree volumes based on dendrometer measurements with tree volumes compiled from felled trees. Most of these studies have compared total tree volumes including bark. Arvanitis (1967) compared outside-bark felled tree volumes for 29 white pine trees with estimated volumes via Barr and Stroud and Spiegel Relascope. The Spiegel Relascope volumes were 4.2 percent low and the Barr and Stroud volumes were 0.2 percent high as compared to felled trees but differences were not statistically significant (probability of 0.90).

Bell and Groman (1971) also compared outside bark volumes for 12 felled and calipered Douglas-fir trees with volumes based on Barr and Stroud dendrometer measurements. The Barr and Stroud volumes exceeded felled trees by only 0.35 percent. Bell and Groman also concluded that smaller

diameters were measured with a larger percent error than large diameters and that slight differences in measured height to point of observation significantly affected diameter accuracy. They found that distance from the subject tree is less important than visibility of the tree. Finally, they pointed out that accuracy in height and segment length measurement decreases rapidly in both feet and percent as the vertical angle increases.

Bower (1971) compared outside bark volumes on climbed trees measured by caliper (five 12-inch and five 14-inch dbh loblolly pines) with Zeiss Telemeter Teletop and Barr and Stroud dendrometer volumes. The dendrometer based estimates of tree volume, surface, length, (Grosenbaugh 1967c), or sum of diameters did not differ significantly (0.05 significance level) from estimates based on caliper measurements. Both dendrometers overestimated measured volume by about 1 percent.

All of these previous studies compared volumes outside bark. A study in eastern Oregon (Bower 1972) compared estimated volumes inside and outside bark as obtained from Barr and Stroud measurements, bark thickness at breast height, and Grosenbaugh's hyperbolic function (STX option 2), with felled tree inside and outside bark measured volumes. Results are summarized in Table 1. Results for ponderosa and lodgepole pine are as might be expected, very accurate estimates via dendrometer for outside bark volume but some falldown in accuracy when translating outside bark measurements to estimated inside bark diameters. Results indicate that more work is needed to refine bark thickness estimators. The Barr and Stroud outside-bark volumes were less accurate for Douglas-fir and white fir in this particular study and the bark thickness conversions were compensating such that inside bark volumes were closer to the measured volume i.b. than in the case of outside bark volumes.

Note also that volume tables by King and Turnbull for Douglas-fir and by Bower for ponderosa pine (both unpublished) and by Dahms (1971) for lodgepole provided inside bark volume estimates of comparable accuracy to the Barr and Stroud volumes.

CONCLUSIONS

Dendrometers provide a reasonably fast and accurate means of obtaining outside bark taper data for many purposes. There are a number of constraints to dendrometry applications, however, including weather conditions, brush, stand density, crown density, which should be considered when planning a field dendrometry project. In addition, a number of mensurational considerations are of equal or greater importance than the level of accuracy of the dendrometer itself. These include such things as frequency of measurement on a tree bole in relation to taper, the algorithm of tree shape, bark thickness estimators, selection of trees for local volume equation estimators, and models to use for stand volume estimation.

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Table 1.--Tree volume estimation via Barr and Stroud, volume table and felled trees

				Total Stem Cubic Foot Volume				
Species	No. Trees	DBH Range (inches)	Bark	Felled Tree	B & S	Percent Error	EQ	Percent Error
Ponderosa Pine	17	4.3 to 20.3	O.B.	25.918	25.841	-0.30	25.145	-2.98
			I.B.	15.792	15.650	-0.90	16.037	+1.55
Lodgepole Pine	12	4.1 to 12.6	O.B.	16.071	15.983	-0.55		
			I.B.	13.302	14.083	+5.87	13.764	+3.47
Douglas-Pine	6	3.6 to 14.5	O.B.	22.647	21.400	-5.51		
			I.B.	18.460	17.767	-3.75	19.292	+4.51
White Fir	8	3.3 to 14.6	O.B.	19.832	19.162	-3.38		
			I.B.	15.655	15.487	-1.07		

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RESUMEN

En este trabajo se describen algunas aplicaciones comunes de dendrometría incluyendo el desarrollo de ecuaciones standard y locales para determinar el volumen de árboles y la acumulación de información sobre el crecimiento y la conicidad del árbol. Se discuten algunos de los problemas asociados con la dendrometría de campo y con los estimados de volumen de árbol, al igual que algunos otros procedimientos para estimación del volumen.

A New Method to Convert Outside Bark Diameters to Inside Bark Diameters for Optical Dendrometry[1]

Paul Van Deusen, Thomas G. Matney, David R. Bower,

and Alfred D. Sullivan[2]

Abstract.--A technique for prediction of inside bark diameter from outside bark diameter and relative height is presented. No inside bark measurement at DBH is required as with previous methods.

INTRODUCTION

Dendrometry measurements provide a complete set of stem taper observations and lead to very accurate outside bark volume estimates. Inside bark volume can be obtained by estimating inside bark diameter (DIB) from outside bark diameter (DOB) and calculating an inside bark volume for each tree. Grosenbaugh has provided three equations to be used with his STX computer program to yield these inside bark estimates:

Model 1 - The assumption is made that the ratio of DBHIB/DBHOB remains constant up the stem

DIB = DOB * DBHIB/DBHOB,

where,

DBHIB = Inside bark diameter at breast height, and

DBHOB = Outside bark diameter at breast height.

Model 2 - The ratio of DIB to DOB is assumed to increase curvilinearly up the stem.

DIB = DOB*(1-[[1-(DBHIB/DBHOB)] QUAN/(DENO-DOB/DBHOB)])

Model 3 - The ratio of DIB to DOB is assumed to decrease curvilinearly up the stem.

DIB = DOB*(DBHIB/DBHOB) [QUAN/(DENO-DOB/DBHOB)]

Grosenbaugh provides values of 1.0 and 2.0 for Quan and Deno, respectively, for Model 2, and values of 9.0 and 10.0 for Model 3. A junction point in the STX program has been provided for a user supplied model for those dissatisfied with these options.

We have derived a fourth model and have fit it to 3700 taper observations from 375 loblolly pines (Pinus taeda L.). These trees were cut at 6 inches above the ground and destructively sampled. Measurements taken included DBH, total height, and DOB and DIB measurements along the stem to a small top diameter. The trees in this fitting data set were from throughout the loblolly pine range (Figure 1.) and were selected at random from a larger data set. They included DBH classes from 3 to 13 inches.

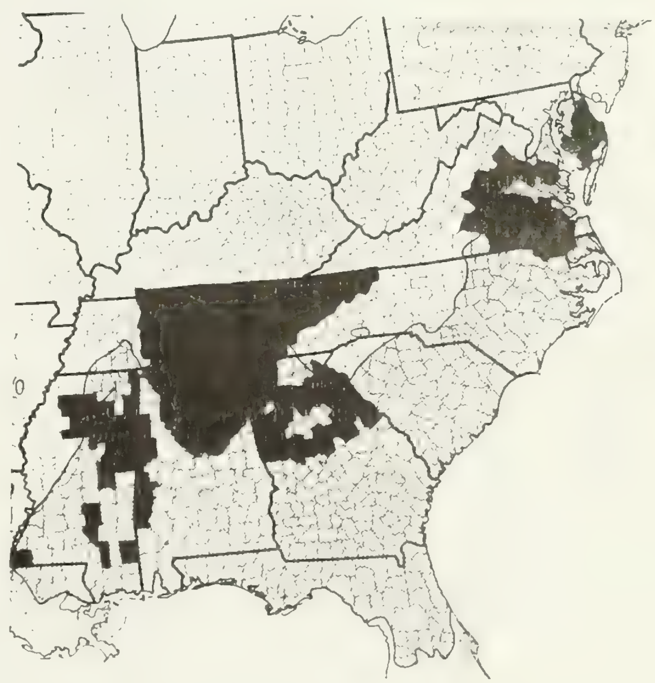

Figure 1.--Plot locations of the study data. The gray area represents the loblolly pine natural range.

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[1] Paper presented at the Arid Lands Resource Inventories Workshop. [La Paz, Mexico, November 30-December 6, 1980]

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PROCEDURE

A nonlinear equation was chosen for this fourth model utilizing variables which could be derived from dendrometer measurements. The model makes no inherent assumptions about the relationship of DIB to DOB along the stem, instead this is determined by the least squares fit:

Model 4 - DIB=DOB*(1-.13046*DOB/DBHOB-.026572*H/TH]
, MSE = .0346

where,

H= The height to the DOB measurement of interest, and
TH = The total height of the tree.

The remaining 827 trees from the original data set were then used to test the predictive ability of this new equation as compared to Grosenbaughs' three models. Note that models 2 and 3 were also fit to 375 loblolly pines in the fitting data set. Estimates of inside bark volume to top diameters ranging from zero to seven inches were determined by each of the four models. A volume for each bolt was calculated using Smalians' formula from the estimated DIB. These were accumulated and the estimated total inside bark volume was compared to the observed volume derived from the actual DIB measurements.

A variable DBAR was found for each of the 827 trees where:

$$DBAR = \sum_{i=1}^{N} (VOB-VPR),$$

VOB = Observed inside bark volume,
VPR = Predicted inside bark volume, and
N = Number of bolts in the tree.
A student T-test was then performed at the .05 level to test the null hypothesis, Ho: DBAR=0. The results of these tests are presented in tables 1-4. Models 1 and 3 perform equally due to the very small parameters given by the least squares fit to model 3. Model 2 yields the worst results and model 4 yields the best results in terms of the amount of times Ho was not rejected and the size of DBAR. Although models 1 and 3 yield the fewest rejections of Ho for top diameters greater than 4 inches, model 4 always gives a smaller average DBAR. An important difference between model 4 and the other models is that model 4 requires no DBHIB measurement. This will save time in the field and eliminate a possible source of error as DBHIB is difficult to measure accurately. An incorrect DBHIB measurement will bias the entire tree volume when using Grosenbaughs' models.

An example will prove useful to illustrate the importance of the average DBAR presented in the tables. Suppose five thousand acres are being cruised with 100 merchantable trees per acre, or 500,000 trees in total. Multiplying the average DBAR from models 3 and 4 by 500,000 trees will result in the total bias in the estimate of inside

Table 1. Model 1. - Comparison of observed with predicted inside bark volumes. (DBAR = observed volume - predicted volume.)

N of trees	Failed to Reject Ho: DBAR=0	Average DBAR	Upper Diameter Limit
827	357	-.0214	0
827	357	-.0220	1
827	357	-.0232	2
823	382	-.0254	3
776	442	-.0251	4
638	424	-.0251	5
418	305	-.0282	6
227	175	-.0293	7

Table 2. Model 2. - Comparison of observed with predicted inside bark volumes. (DBAR = observed volume - predicted volume.)

N of trees	Failed to Reject Ho: DBAR=0	Average DBAR	Upper Diameter Limit
827	224	.0918	0
827	224	.0924	1
827	222	.0951	2
823	237	.1063	3
776	283	.1323	4
638	280	.1775	5
418	209	.2350	6
227	120	.3024	7

Table 3. Model 3. - Comparison of observed with predicted inside bark volumes. (DBAR = observed volume - predicted volume)

N of trees	Failed To Reject Ho: DBAR=0	Average DBAR	Upper Diameter Limit
827	357	-.0214	0
827	357	-.0220	1
827	357	-.0232	2
823	382	-.0254	3
776	442	-.0251	4
638	424	-.0251	5
418	305	-.0282	6
227	175	-.0293	7

Table 4. Model 4. - Comparison of observed with predicted inside bark volumes. (DBAR = observed volume - predicted volume)

N of trees	Failed To Reject Ho: DBAR=0	Average DBAR	Upper Diameter Limit
827	419	.0012	0
827	419	.0006	1
827	416	-.0004	2
823	426	-.0005	3
776	437	.0015	4
638	395	.0005	5
418	266	-.0013	6
227	156	-.0150	7

bark volume for the cruise, given that all other measurements were unbiased. Model 3 will over-estimate total inside bark cubic foot volume by 10725, while model 4 will underestimate the volume by 625 cubic feet. Clearly, model 4 is worth implementing.

CONCLUSION

Grosenbaugh has provided the only equations to estimate DIB from DOB in the literature to date. Several authors have made recommendations about which model is most suitable for certain species (e.g. Boehmer and Rennie 1976, Wiant and Koch 1974, and Mesavage 1969), but none have suggested a new model entirely. The new model presented here is meant to demonstrate methodology and to provide an alternative that does not require the measurement of DBHIB, which is time consuming in the field and prone to error. Although a large data set was used to derive and test the model, the trees ranged in diameter from only 3 to 13 inches. The equation would not be reliable when used beyond this range or with a different species. The model should be fit to data from the species of interest including an adequate range of diameters before being used.

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RESUMEN

Se presenta una técnica para predecir el diámetro de la corteza interna utilizando el diámetro de la corteza externa y la altura relativa. No es necesario medir la corteza interna a la altura del pecho (DBH) como se requería en métodos anteriores.

Estimation of Merchantable Volume and Height of Natural Grown Slash Pine Trees[1]

Thomas G. Matney

Alfred D. Sullivan[2]

Abstract.--Methods for estimating merchantable volume and height to any top diameter limit are described. Specific coeffients for merchantable volume and height prediction equations presented are applicable to natural grown slash pine trees.

INTRODUCTION

Accurate methods of calculating volume and height to any top diameter limit are fundamental to multiple product resource inventories and yield prediction. This paper describes an approach to estimating merchantable cubic foot volume and height to any merchantable top diameter limit. The method described is an extension and refinement of the merchantable volume to total volume ratio prediction method introduced by Burkhardt (1977).

In the approach, equations for estimating merchantable cubic foot volume (ob/ib) to total tree cubic foot volume (ob/ib) ratio to any top diameter limit (ob/ib) along with companion total tree volume (ob/ib) equations are developed. Merchantable volume is thus obtained by multiplying a predicted volume ratio by a predicted total tree volume. Equations for calculating height to any top diameter limit (ob/ib) are subsequently derived from the merchantable volume equations.

While the specific coefficients presented for derived equations are only applicable for predicting merchantable volumes and height of natural grown slash pine trees (*Pinus elliottii* Engelm), the methods can be used for other species.

Data

Sixty destructively sampled slash pine trees from 6 natural stands on National Forest land in southern Mississippi provided the taper-volume data. Sample stands were equally distributed among low, medium and high site quality land.

Within these broad site classes, insofar as was possible, one tree in each DBH class from 1 to 20 inches was selected. However, insufficient numbers of large trees in the low site quality classes necessitated taking additional trees from the higher site quality classes to obtain three trees in each diameter class greater than 16 inches. Actual sample trees ranged from 1.7 to 19.9 inches in DBH. Total tree height ranged from 16 to 107 feet. The average base age 50 site indices for the low, medium and high site sample stands were 75, 85, and 95 feet, respectively.[3]

The main stem of each sample tree was bucked at four-foot intervals beginning at a 0.5 foot stump height. Diameter (ib and ob) was then measured with a ruler at the base of each bolt. Diameter (ib and ob) also was measured on cross sections made at one-foot intervals in the base bolt for a more accurate determination of volume in the bolt.

Smalian's formula was used to calculate cubic-foot volume (ib and ob) of each sectional length. Volume above the last four-foot bolt was computed by treating the segment as a cone. Volume in the cone was added to the sum of section volumes above the 0.5-foot stump height to obtain total tree volume. Merchantable volume (ib and ob) to total volume (ib and ob) ratios were calculated to the top of each cross section. A total of 1170 merchantable volume (ib and ob) to total volume (ib and ob) ratios were available for analysis in each volume designation.

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[1]Paper presented at the Arid Land Resources Inventories workshop, La Paz, Mexico, November 30 December 6, 1980.

[2]The authors are assistant professor and professor, respectively in the Department of Forestry, Mississippi Agricultural and Forestry Experiment Station at Mississippi State University, Mississippi State, MS 39762.

[3]Site index was calculated from the average estimated base age 50 site indices of five dominant and codominant stand trees using the stie index curves in Miscellaneous Publication 50(1929).

Methods

Volume ratio equations. The first step of analysis was to develop equations for each of the following prediction cases:

1. ratio of merchantable cubic foot volume (ob) to total cubic foot volume (ob) for any outside bark top diameter limit.

2. ratio of merchantable cubic foot volume (ob) to total cubic foot volume (ob) for any inside bark top diameter limit,

3. ratio of merchantable cubic foot volume (ib) to total cubic foot volume (ib) for any outside bark top diameter limit, and

4. ratio of merchantable cubic foot volume (ib) to total cubic foot volume (ib) for any inside bark top diameter limit.

The volume ratio data were classified into three height classes to determine if the volume ratio curves differed for trees of different heights. Inspection of these curves showed marked differences in curve shape between height classes. The volume ratio curves steepened with increasing total tree height for all prediction cases. Similar classifications on DBH showed no evident relationship with DBH.

Initially restricting efforts to prediction case 1, a model was sought that would adequately fit individual trees of any given physical dimensions. Only models logically restricted to predict a volume ratio of 1 for a top diameter limit of zero were considered. After investigating numerous models, the model that proved the best was the nonlinear model

$$R_o(X_o) = 1-[1-\exp[(-B_{o1}\tan(B_{o2}X_o)]]^{B_{o3}}, \qquad (1)$$

where

$R_o(X_o)$ = ratio of merchantable cubic foot volume (ob) to total cubic foot volume (ob),

$X_o = d_o/D_o$ = ratio of merchantable top diameter (ob) limit to diameter (ob) at breast height (4.5) feet above ground),

exp = exponentiation to the base of the Naperian logarithm,

tan = tangent of an angle expressed in radians, and

B_{oj}'s = parameters to be estimated.

Regression analysis of the estimated parameters (B_{oj}'s) for all 60 trees, using the independent variables of DBH and total tree height (H), demonstrated that the parameter B_{o2} was strongly related to height, and that the best regression equation for estimating B_{o2} was

$$B_{o2} = B'_{o2}H^{B_{o4}}, \qquad (2)$$

where, B'_{o2} and B_{o4} are parameters to be estimated. No other model parameters were significantly related to either DBH or H.

Substitution of equation 2 for B_{o2} of equation 1, resulted in the following equation for simultaneous estimation of its parameters:

$$R_o(X_o) = 1-[1-\exp[-B_{o1}\tan(B'_{o2}H^{B_{o4}}X_o)]]^{B_{o3}}. \qquad (3)$$

Further analysis of the prediction case 1 data showed that the variance of the volume ratios increased with increasing X_o. Experimentation with differing weight functions indicated that the weight function $W_o(X_o) = (1+X_o)^{-10}$ would provide the uniform variance across X_o required for the non-linear least squares fitting of equation 3.

An analysis of the data applicable to prediction case 4 comparable to that conducted for prediction case 1 resulted in the prediction model

$$R_i(X_i) = 1-[1-\exp[-B_{i1}\tan(B'_{i2}H^{B_{i4}}X_i)]]^{B_{i3}}, \qquad (4)$$

where

$R_i(X_i)$ = ratio of merchantable cubic foot volume (ib) to total cubic foot volume (ib),

$X_i = d_i/D_i$ = ratio of merchantable top diameter (ib) to diameter (ib) at breast height, and

B_{ik}'s = parameters to be estimated from the data.

Equation 4 differs from equation 3 in that the diameter ratio of X_i was substituted for the diameter ratio X_o. When only outside bark diameter at breast height (D_o) is measured an estimate of inside bark diameter at breast hight (D_i) can be calculated using

$$D_i/D_o = a_0\exp(-a_1/D_o), \qquad (5)$$

where a_0 and a_1 are parameters to be estimated. The weighting function $W_i(X_i) = (1+X_i)^{-10}$ yields the required homogenous variance across X_i for equal precision of the fitted equation 4 for all X_i's.

Predictions for prediction cases 2 and 3 were achieved by developing a single equation for con-

verting outside volume ratio to inside bark volume ratio. The conversion equation developed was

$$R_i = R_o^{(C_0+C_1V_i/V_o)^{-1}}, \qquad (6)$$

where

R_i = ratio of merchantable volume (ib) to total volume (ob),

R_o = ratio of merchantable volume (ob) to total volume (ob),

V_i = total tree cubic foot volume (ib),

V_o = total tree cubic foot volume (ob), and

C_j's = parameters to be estimated from the data.

To find the ratio of merchantable volume (ib) to total volume (ib) to an outside bark top diameter, the merchantable volume (ob) to total volume (ob) ratio (R_o) to an outside bark top diameter is calculated using equation 3. Equation 6 is then used to convert the calculated R_o the desired inside bark ratio (R_i). For the converse conversion, equation 6 can be rewritten as

$$R_o = R_i^{C_0+C_iV_i/V_o}. \qquad (7)$$

The advantage of using equation 6 or 7 versus deriving separate equations for prediction cases 2 and 3 is that the equations avoid the potential problem of having inside and outside bark volume ratios cross illogically. If independent equations are used to estimate R_o and R_i then it could be possible that predicted R_i would be greater than R_o, particularly at the small top diameter limits.

Merchantable height. Estimating equations for height to any inside and outside bark top diameter are readily derived from the defined merchantable volume (M) equations $M_i(X_i) = V_iR_i(X_i)$ and $M_o(X_o) = V_oR_o(X_o)$, respectively. The development of these merchantable height prediction equations requires that equations for computing the derivative of bole length with respect to top diameter limit be derived from the merchantable volume equations. These derived equations can then be integrated between a top diameter limit of zero and any other top diameter limit; and the result subtracted from total tree height to calculate merchantable height.

Consider first the derivation of the rate of change equation for predicting height to any outside bark top diameter limit from the merchantable volume equation $M_o(X_o) = V_oR_o(X_o)$. By the chain rule of differential calculus, the rate of change of bole length (L) with respect to top diameter limit d_o is

$$dL/dd_o = [dM_o(X_o)/dd_o][dL/dM_o(X_o)]. \qquad (8)$$

The derivative $dM_o(X_o)/dd_o$ is obtained directly from equation 3.

$$dM_o(X_o)/dd_o = V_o dR_o(X_o)/dd_o = -B_{o1}B_{o2}B_{o3}H^{B_{o4}}V_oD_o^{-1}[1+[\tan(B_oH^{B_{o4}}X_o)]^2]\exp[-B_{o1}\tan(B_{o2}H^{B_{o4}}X_o)][1-\exp[-B_{o1}\tan(B_{o2}H^{B_{o4}}X_o)]]. \qquad (9)$$

An expression for $dL/dM_o(X_o)$ can be calculated by noting that for any top diameter limit d_o, the change in $M_o(X_o)$ for a small change in length is

$$dM_o(X_o)=CS(d_o)dL, \qquad (10)$$

where $CS(d_o)$ is the cross sectional area of a circle of diameter d_o. Thus, upon rearranging equation (3) and taking the limit as L goes to zero,

$$dL/dM_o(X_o) = 1/CS(d_o). \qquad (11)$$

To insure that the dimensional units of L are the same as the dimensional units of total tree height, the dimensions of $CS(d_o)$ must be chosen to make the right and left hand sides of equation 8 match. If for example, volume is in cubic meters, height is in meters and diameter is in centimeters, $CS(d_o)$ must be in square meters (i.e. $CS(d_o) = [\pi/(4)(100)^2]d_o^2$).

The respective dimensional units of volume, height and diameter used in this study are cubic feet, feet, and inches. Thus

$$dL/dM_o(X_o) = (576/\pi)(1/d_o^2) \qquad (12)$$

or replacing d_o by D_oX_o,

$$dL/dM_o(X_o) = (576/\pi)(1/D_o^2X_o^2). \qquad (13)$$

Substituting equations 9 and 13 for their respective expressions in equation 7 yields the required result, that is

$$dL/dd_o = -B_{o1}B_{o2}B_{o3}H^{B_{o4}}V_oD_o^{-3}X_o^{-2}(576/\pi)[1+[\tan(B_{o2}H^{B_{o4}}X_o)]^2]\exp[-B_{o1}\tan(B_{o2}H^{B_{o4}}X_o)][1-\exp[-B_{o1}\tan(B_{o2}H^{B_{o4}}X_o)]]. \qquad (14)$$

Exactly the same reasoning can be used to derive the rate of change function for inside bark top diameter limits (dL/dd_i) from the equation, $M_i(X_i) = V_iR_i(X_i)$. The resulting equation is:

$$dL/dd_i = -B_{i1}B_{i2}B_{i3}H^{B_{i4}}V_iD_i^{-3}X_i^{-2}(576/\pi)[1+ [\tan(B_{i2}H^{B_{i4}}X_i)]^2]\exp[-B_{i1}\tan(B_{i2}H^{B_{i4}}X_i)] [1-\exp[-B_{i1}\tan(B_{i2}H^{B_{i4}}X_i)]]. \quad (15)$$

Total tree cubic foot volume. A desirable property of merchantable length prediction is that merchantable length between a top diameter of 0 and a top diameter (ib or ob) at DBH height should equal H-4.5 feet. The complexity of the nonlinear models presented here prevented the imposition of this constraint on the fitted models. One way of imposing this restriction, however, is to accept a total tree volume such that calculated merchantable length between a top diameter of 0 and the top diameter at DBH height equals H-4.5. That is, accept for total tree inside bark cubic foot volume the volume

$$V_i = (H-4.5)/\int_{D_i}^{0}(dL/d_i)dd_i, \quad (16)$$

and accept for total tree outside bark cubic foot volume the volume

$$V_o = (H-4.5)/\int_{D_o}^{0}(dL/d_o)dd_o. \quad (17)$$

Evaluation of the differences between the observed total tree volumes (ib and ob) and those calculated using equations 16 and 17 revealed very close agreement between observed and estimated values. Additionally, for each of the 60 trees comparisons were made of the observed with estimated with estimated obtained from the commonly used volume equations,

$$V = C_0^1 + C_1^1D_o^2H \quad , \quad (18)$$

$$V = C_0^2D_o^{C_1^2}H^{C_2^2} \quad , \text{ and} \quad (19)$$

$$V = D_o^2/(C_0^3 + C_1^3/H) \quad (20)$$

where

V = total stem cubic foot volume (ob or ib), and

C_j^i's = coefficients to be estimated from the data.

Equation 18 is the commonly used combined-variable model (Spurr, 1952); equation 19 is the Schumacher model (Schumacher and Hall 1933); and equation 20 is a model suggested by Honer (1965).

Evaluation of the observed minus predicted volumes of these equations indicated that volume estimates obtained from equations 16 and 17 were at least as accurate. Hence, equations 16 and 17 were accepted as the best equations for calculating volume.

Volume estimation using the latter equations requires numerical integration since no closed forms exist for the integrals. As this is an arduous task for calculating total volume, solutions were made for 200 combinations of D_o, and H to use in developing a volume prediction equation. The resulting equation was

$$V/D^2 = g_{0k}H^{g_{1k}}\exp(g_{2k}H^{-g_{3k}}), \quad (21)$$

where

V = total tree cubic foot volume (ib or ob),

D = D_i for inside bark volume and D_o for outside bark volume, and

g_{jk}'s = parameter to be estimated.

Results and Discussion

The fitted and derived equations required for estimating merchantable volume and height are presented below.

--Ratio of cubic foot volume (ob) to total cubic--foot volume (ob) to an outside bark top

$$R_o(X_o) = 1-[1\exp[-.89911\tan(1.0024 H^{.059355}X_o)]]^{3.9994} \quad (22)$$

N = 1170 , R^2 = NA , Sy.x = .002204, $\bar{Y}$ = .612

--Ratio of cubic foot volume (ib) to total cubic--foot volume (ib) to an inside bark top

$$R_i(X_i) = 1-[1-\exp[-.69374\tan(1.1253 H^{.040763}X_i)]]^{3.4451} \quad (23)$$

N = 1170 , R^2 = NA , Sy.x = .002003, $\bar{Y}$ = .604

--Ratio of cubic foot volume (ib) to total cubic--foot volume (ib) to an outside bark top

$$R_i(X_o) = [R_o(X_o)]^{[.69627 + .32670V_i/V_o]^{-1}} \quad (24)$$

N = 1170 , R^2 = 99.9 , Sy.x = .00700 , $\bar{Y}$ = .604

--Ratio of cubic foot volume (ob) is total cubic-- foot volume (ob) to an inside bark top

$$R_o(X_i) = [R_i(X_i)]^{[.69627 + .32670V_i/V_o]} \qquad (25)$$

$N = 1170$, $R^2 = 99.6$, $Sy.x = .00900$, $\bar{Y} = .612$

---------Total tree cubic foot volume (ob)--------

$$V_o/D_o^2 = .0055138\ H^{.84989}\exp(-24.53213\ H^{-1.76663}) \qquad (26)$$

$N=200$, $R^2 = 99.9$, $Sy.x = .00008$ $\bar{Y} = .189$

--------Total tree cubic foot volume (ib)--------

$$V_i/D_i^2 = .0048923\ H^{.886763}\exp(-16.98408\ H^{-1.56522}) \qquad (27)$$

$N = 200$, $R^2 = 99.9$, $Sy.x = .00003$ $\bar{Y} = .178$

-------Inside bark diameter at breast height------

$$D_i/D_o = .8945\exp(-.22108/D_o) \qquad (28)$$

$N = 60$, $R^2 = 98.0$, $Sy.x = .03532$, $Y = .893$

----Merchantable height to an outside bark top----

$$h(d_o) = H - \int_0^{d_o} 660.878(t_o/D_o)^{-2} V_o D_o^{-3} H^{.059355}[1+W^2]$$

$$\exp[-.89911(W)]$$

$$[1-\exp[-.89911(W)]]^{2.9994}\ dt_o,$$

where

$$W = \tan[1.0024H^{.059355}(t_o/D_o)] \qquad (29)$$

$N = 1170$, $R^2 = 99.4$, $Sy.x = 2.5$, $\bar{Y} = 31.2$

-----Merchantable height to an inside bark top----

$$h(d_i) = H - \int_0^{d_i} 493.105(t_i/D_i)^2 V_i D_i^{-3} H^{.040763}[1+W^2]$$

$$\exp[-.69374(W)][1-\exp[-.89374(W)]]^{2.4451}dt_i,$$

where

$$W = \tan[1.1253\ H^{.040763}(t_i/D_i)] \qquad (30)$$

$N = 1170$, $R^2 = 99.3$, $Sy.x = 2.6$, $\bar{Y} = 31.2$

The coefficient of determination, standard error of prediction and the mean of the dependent variable are shown under each equation and are denoted by R^2, Sy.x, and, $\bar{Y}$, respectively. The R^2 values for equations fitted using weighted least squares are designated as NA to indicate that R^2 is not appropriate for the case.

The large R^2 values, when applicable, and the small Sy.x values for the volume ratio equations and height equations, indicate a high degree of correspondence between the observed and predicted values . Overall evaluation of observed minus predicted values for all possible prediction conditions showed no evident biases across the surrogates of DBH, V_o, V_i, X_i, or X_o.

Example Application

Suppose it is desired to estimate merchantable cubic foot volume (ob and ib) and height to a 5-inch top diameter (ob) of a slash pine tree 10 inches in DBH and 70 feet tall.

First calculate total tree cubic foot volume (ob) using equation 26.

$$V_o = .0055138(70)^{.84989}10^2\exp[(-24.53213\ (70)^{-1.76663}]$$

$$= 20.12\ ft^3.$$

Next calculate diameter inside bark at breast height from equation 28.

$$D_i = .8945\exp(-.22108/10)$$

$$= 8.75\ in.$$

Then, using the calculated inside bark diameter calculate total tree cubic foot volume (ib) from equation 27.

$$V_i = .0048923(70)^{.886763}(8.75)^2\exp[-16.98408\ (70)^{-1.56522}]$$

$$= 15.87\ ft^3.$$

Now, from equation 22, determine the merchantable cubic foot volume (ob) to total tree cubic foot volume (ob) ratio to the 5-inch top (ob).

$$R_o(5/10) = 1-[1-\exp[-.89911\tan[1.0024(70)^{.059355}(5/10)]]^{3.9994}$$

$$= .942$$

Thus the merchantable cubic foot volume (ob) of the tree is

$$M_o(5/10) = (20.12)(.942) \doteq 18.95\ ft^3.$$

Merchantable cubic foot volume (ib) to the 5-inch top (ob) is calculated by converting $R_o(5/10)$ to an inside bark ratio using equation 24, and multipling the resultant ratio by total tree inside bark cubic foot volume.

$$R_i(5/10) = (.942)^{[.69627 + .32670(15.85/20.12)]^{-1}}$$

$$= .939 \quad , \quad \text{and}$$

$$M_i(5/10) = (15.85)(.939) = 14.89 \text{ ft}^3.$$

Finally, calculate the estimate of merchantable height to the 5 inch top (ob) from equation 29. Accomplishing this requires numerical evaluation of the indicated integral. That is, one must evaluate the integral

$$I = \int_0^5 (-dl/dt_o)dt_o$$

$$= \int_0^5 660.878(t_o/D_o)^{-2} V_o D_o^{-3} H^{.059355} [1+W^2)$$

$$\exp[-.89911(W)]$$

$$[1-\exp[-.89911(W)]]^{2.9994} dt_o,$$

where $W = \tan[1.0024(70)^{.059355}(t_o/10)]$.

A simple and accurate methods for evaluating I is the composite form of Simpson's quadrature rule (Conte and deBoor 1972):

$$I[x_0,x_n] = (h/6) \sum_{i=1}^{n} [f_{i-1} + 4\, f_{i-\frac{1}{2}} + f_i], \qquad (31)$$

where

$I[x_0,x_n] = \int_{x_0}^{x_n} f(x)dx$ = the integral of the function $f(x)$ on the interval ranging from x_0 to x_n,

n = number of equal width (h) subintervals the interval $[x_0, x_n]$ is partitioned into,

h = subinterval width,

$f_i = f(X_0 + ih)$ and is the value of the function $f(x)$ at $x_i = x_0 + ih$, and

$f_{i-\frac{1}{2}} = f(x_0 + (i-\frac{1}{2})h)$ and is the value of the function at the midpoint of each subinterval (i.e. $x_{i-\frac{1}{2}} = x_0 + (i-\frac{1}{2})h$).

Using an interval of width h = 1 inch, the required information for approximating the integral defined by equation 31 is summarized below.

i	$t_i = t_0 + ih$	$f(t_i) = - dl/dt_o \vert t_i$
0	0.0	0.0000
½	0.5	1.1666
1	1.0	2.0685
1½	1.5	2.7938
2	2.0	3.4038
2½	2.5	3.9420
3	3.0	4.4410
3½	3.5	4.9256
4	4.0	5.4158
4½	4.5	5.9280
5	5.0	6.4759

Thus by equation 31 the approximate integral I is,

I[0,5] = 18.7 ft., and

thus

h(5/10) = 70.0-18.7 = 51.3 ft.

Computer Program

A computer program was written to facilitate the application of the merchantable volume and height prediction equations developed in this paper. The program was written in FORTRAN V on a Univac 1108 computer, but is adaptable with minor modification to other computers.

The program produces tables of merchantable cubic foot volumes and heights according to user specified inputs. The program can also produce tables showing board foot volumes (Doyle, Scribner, or International) and veneer yields. Users may, however, adapt the base subroutines to develop programs for their prediction needs. Card decks of the program are available from the authors on request.

Conclusions

Precise estimates of merchantable cubic foot volume and height can be obtained using merchantable volume to total volume ratio equations. The advantages of this approach over taper equations or separate prediction equations to various top limits are several. First, merchantable volume is calculated directly and thus the equations are easier to apply than are taper equations.

Second, taper equations are fitted to optimize the prediction of diameter or diameter squared (Matney and Sullivan 1979; Max and Burkhart 1977; and others), whereas ratio equations are essentially fitted to optimize predictions of volume. Thus, estimates of volume obtained from ratio equations

should be more precise than those indirectly estimated by integration of taper equations.

Third, mathematical constraints imposed on the ratio equations prevent prediction of volumes to large top limits exceeding those predictions to a smaller top limit as is commonly observed for unconstrained volume equations to differing top limits (Burkhart 1977). Constraining volume equations to various top limits to differ by a constant amount can eliminate this difficulty (Bailey and Clutter 1970), but as pointed out by Burkhart (1977), for the larger top limits, the slope of the merchantable volume line becomes steeper and thus the parallel line assumption fails.

Although the merchantable volume and height equations presented are only applicable to natural grown slash pine trees, the procedure should work well with other species. The approach will be particularly useful where the primary objective is to obtain accurate estimates of merchantable cubic foot volumes. Merchantable height estimates computed from the merchantable volume equations however, should, be sufficiently precise for most applications.

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RESUMEN

Se describen aquí los métodos para estimar el volumen comerciable y la altura para cualquier límite de diámetro en la copa de un árbol. Los coeficientes específicos para el volumen comerciable y las ecuaciones que se sugieren aquí para predecir altura, son aplicables a los árboles de pino (slash) de desarrollo natural.

Combined Forest Inventory Using 35mm and 70mm Aerial Photography with an Extensive Ground Survey in Pinus caribaea Plantations in the Savannah Plain, Venezuela[1]

B. Rhody[2]

Abstract.--During 1979 a combined forest inventory using large-scale aerial photography and an extensive ground survey has been carried out in P. caribaea plantations in the Orinoco basin, Venezuela.
The camera system comprised 2 Hasselblad EL 500 with fixed (4.10 m) base and a 35 mm Canon camera as a flight path tracking camera. The ground survey is characterized by permanent sample plots within a cluster (a square with a relascope point at each corner with randomly selected sample tree felled for growth and volume estimation - derivation of a tariff from sample tree data). Aerial photos served also for the delineation of 3 types of stand structure, the assessment of understocked areas and an estimation of typical defects such as witchbroom and fox-tailing.

INTRODUCTION

The Government of Venezuela, through the combined efforts of the state-owned Guayana Coorporation (CVG) and National Reforestation Company (CONARE) has been establishing large commercial industrial plantations of Pinus caribaea on the grassland savannas of eastern Venezuela. Nearly 50,000 ha have been planted in 1969.

For obtaining information on the present structure, standing volume, mortality and growth, an inventory combining terrestrial sampling and large-scale aerial photography has been carried out in 1979 by the author. A Camera system comprising 2 Hasselblad EL 500 cameras with fixed base (4.10) and a 35 mm Canon camera employed as a flight path tracking camera has been used. The terrestrial sampling was characterized by permanent sample plots within a block of 50 x 50 m.

METHODS AND PROCEDURES

The combined, two-phase inventory for collection of basic data comprises the following components:

Phase 1: Aerial photo inventory

a) photo coverage of the whole area (100 %) at medium scale of approximately 1:30,000 for area assessment and for mapping procedures;

b) aerial photography with 1:10.000 35 mm-photo strips of forests at definite intervals (10 % of plantation area);

c) aerial photography of large-scale 1:2,500 stereoscopic photo plots with photogrammetric plotting and evaluation of basic sample tree data.

Phase 2: Terrestrial sampling

a) sample tree measurements on fixed radius or variable (relascope) plots in a block system, using blocks of 50 m side-length, containing 4 relascope points including 1 fixed radius plot per block with polar coordinates of sample trees being recorded.

EQUIPMENT FOR AERIAL PHOTO INVENTORY

Equipment for the 35 mm-camera (continuous coverage and strip sampling)

Continuous strips used for area adjustment are photographed with a 35 mm-Canon F1 camera, with motordrive for film magazines, holding 250 frames.

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[1] Paper presented at the Arid Land Resource Inventories workshop, Nov. 30-Dec. 6, 1980, La Paz, Mexico.

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Accessories used were:

Wide angle lenses of f = 17 mm, and f = 20 mm power pack for remote control;

automatic diaphragm control;

timer, data-back control unit for identification and numbering of frames.

Stereo-camera system for photo sampling

The stereo-camera system used for taking aerial photographs consists of two 70 mm Hasselblad EL 500 cameras, with the following accessories:

6 magazines for 70 frames capacity;

1 timer, 1 synchronizer, exposuremeter, 12 volt battery pack as a common source of power for all cameras;

1 sighting device for flight path adjustment and aimed photography.

Equipment and instruction for installation and orientation of cameras

For the attachment of cameras and for appropriate relative and absolute orientation the following accessories are needed:

2 camera platforms for EL 500 cameras (adaptable to different types of light aircraft) with 2 spoilers for the camera housings;

2 aluminium casings with access to all camera functions;

1 highly sensitive cross level;

1 clamp for attachment of 35 mm Canon (adaptable to different types of light aircraft);

1 jack for lifting tail-wheeled aircraft.

The orientation and horizontation of camera planes is achieved by means of a sensitive cross level, using also 4 adjustment screws. The stereo-camera system has been designed exclusively for highdecker air-craft with wing struts. Therefore, it is necessary that equivalent types of aircraft are available in particular as far as the wing-construction is concerned. The Cessna 150 or 170, Piper PA 12 or PA 18 or the Maule Strata are very well suited for these purposes. For adjustment and orientation of stereo-cameras some planes must be brought into horizontal position by lifting the tail-end with a trestle of 1.3 m height, a mobile crane, a fork lift or similar hoisting equipment. If the aircraft cannot be lifted into flight position, a metal wedge whose angle corresponds to the inclination of the tail-section is placed on the camera housing and camera adjustments with the cross level proceeds as above. For Cessna aircraft a lifting is not nesessary.

The above instructions apply also to the 35 mm Canon camera where the cross-level is placed on the protective casing(RHODY 1977).

Instructions for the photo flight

An authorization to take pictures of the project area must have been obtained in advance and generally the flight schedule must also be submitted to the air-controller 1-2 hrs. prior to the intended mission. Measurement of prevailing light conditions by the exposuremeter is necessary if automatic diaphragm control is not available. Camera functions, such as distance and exposure time must be determined and fixed with tape to avoid loosening by vibration during the flight. The following checks are also required:

control of battery dependent functions,

removal of magazine cover plates,

activation of the automatic diaphragm control,

proper function of the shutter is controlled by twice releasing both cameras.

Usually, flight data are written on a card-board plate which is positioned beneath the cameras and photographed to simplify identification of films. Other details concerning the flight plan are taken from a computer list showing the relationships of flighing height, focal lengths, area covered by one frame, exposure interval, airspeed, and scale obtained.

Starts and landings are dependent on the magazine capacity. On each flight a maximum of 70 stereo-photos (70 mm) and 250 single-photos with variable overlap (35 mm) can be taken.

Ground support

For the preparation of equipment and

assistance in setting ground signals a forest engineer with a good knowledge of mensuration techniques in particular with knowledge of optical instruments is a valuable aid. Radio contact between the aircraft and the ground support crew is necessary requiring that the equipment can be tuned into the aircraft's frequency. This equipment must be portable and have approxmately 10 km reach. Also a technician should be available for assisting with the mounting of cameras and the marking of boundaries of the area to be covered.

In-flight-accessories

Once airborne the cameras are monitored by remote controls. The adjustment of exposure intervals requires a pocket computer with digital timer, while other variables are recorded on tape after reading the respective equipment, viz., altimeter, stopwatch etc. An aiming device consisting of a monocular, prisms, wide-angle (fisheye-lens) and holding clamp is attached to the photo-operator's window. It allows to view the signals on the ground and to assist the pilot in flight orientation.

Signalization

Square cardboards are mostly used for marking principle points, along the flight path while triangular and rectangular cardboard sets are combined for signals used as identification and scale reference points.

The coordinates of all cardboard signals must be exactly determined and durably marked if the flights are to be repeated in intervals of several years.

In addition, balloons are set high above the canopy if salient land marks are missing and the approach of the aircraft is difficult to accomplish by navigational means. Generally a hydrogene container fitted with a reduction valve is used for 80 cm-diameter signal balloons white or orange in color.

Films

Color transparencies are the most suitable for photogrammetric plotting and photo-interpretation. Of the many films available Kodak Aerochrome MS Films daylight type in 100 ft. rolls or Kodak Ektachrome ER 5257, 200 ASA, have proved the most reliable and adequate material. For flight path tracking with the 35 mm Canon camera Ilford HP 5 panchromatic film of 400 ASA was most efficient (RHODY 1978).

TERRESTRIAL SAMPLING

The number of field inventory sample plots can be considerably reduced because of the measurements performed on the aerial photographs.

A total of approximately 103 concentric sample plots have been measured, their allocation to age-class blocks within the plantations was proportional to the respective areas.

The samples are systematically distributed along grid lines, and a combination of fixed-area plots and variable plots, using a relascope with different basal area factors has been used for the enumeration. Fixed plot radii have been chosen dependent on tree diameters.

The basal area sample was performed using the mirror relascope with basal area factors 1 or 2 (m^2/ha) depending on the tree diameter and the density of the plantation. Height measurements have been made on 3 trees per plot, the selection was based on the diameter class and continued until a diameter/height regression could be computed.

A number of sample trees had been felled for growth analysis, volume estimation, measuring volume, bark thickness by section and the distance between branch whirls for height increment. In addition, thickness and number of branch stubs have been recorded. Other quality indicators such as decay or termite damage are investigated if the need arises.

Field crews consisted of two men in charge of localizing the plot centres and of doing the enumeration work along the plot-line. Approximately 10 % of the samples have been remeasured by a control crew checking the

accuracy and reliability of the field crews' work. Arrangements have been made to mark the plot centres permanently with short pieces of iron pipe to allow fast relocation at the occasion of a second inventory.

Arrangements had also been made to allow for sampling of insects and fungi found during the survey, especially if there was evidence of an infestation.

It may also be found desirable to use samples from felled trees for physical and chemical investigations, such as mechanical testing of physical properties and of chemical contents in resins and suitability for pulping etc.

Equipment of terrestrial sampling crew

The ground crew consists of 2 men equipped with the following instruments and materials:

2 parabolic calipers for 30 cm and 50 cm ranges to be mounted on collapsible aluminium poles;

1 mirror relascope;

1 Suunto hypsometer;

1 compass with clinometer (400° graduation);

1 caliper fork for angle classes 4-8 cm;

yellow or red spray paint for tree marking and usual tools for data recording (punch-cards);

map to record boundaries of forest types, aerial photographs;

metal rods (25 cm pieces of pipe) to mark sample plot centers;

hammer to drive pipes into the ground;

1 metal detector to relocate plot centers for the control crew.

Instructions for surveying and measurement on the sample plot

Because this was the first time that an inventory was conducted in this region a field instruction had to be designed. Surveying of sample plot centers uses prominent terrain-features taken from the map or marked in the map when approaching the sample-plot area. Directions are established with the compass under consideration of the locally occurring deviation from the map grid. Two points having known coordinates serve for controling the established directions.

Coordinate lines running north/south or east/west have been established in this way and plot centers were surveyed at given distances. The same applied to tracts (closed squares) with 50 or 100 m side length. Where trees obstruct the view, the compass is parallelly displaced along a rail, and displacement corrected afterwards.

After direction and distance of the plot center have been established, the center is marked with the iron pipe which is driven to 3 to 5 cm below ground level. Plot centers are marked by spray-painting the 3 nearest trees at the base, color spot pointing toward the center. Distances are chained by using a steel tape. On permanent plots polar coordinates fix the position of each tree in relation to the plot center. At first the position of every tree within the plot is recorded by reading the angle to magnetic north (azimuth) and distance from plot center. This procedure facilitates relocation of the plot center and a control of the development on the plot at the occasion of a second inventory.
Circular, concentric plots are established where the plot radius depends on the average diameter of the trees encountered on the plot. The following table contains the necessary information.

Plot radii for different diameter trees

dbh (dap) (cm)	plot radii (radio de la parcela) (m)	plot area (area de la parcela) (m^2)
15.0 and over (et ma's)	9.77	300
10.0-14.9	5.64	100
until 9.9 (hasta)	3.99	50

In young plantations a plot with 2.82 m radius and 25 m^2 plot area will be sufficient. The following parameters are measured:

- dbh, caliper arm pointing to plot center;

- height of the three trees closest to the center, and lowest height in plot;
- measurement of upper stem diameter at 0.5 of tree height and 3.5 m above ground;
- measurement of bark thickness and of radial increment by boring;
- estimation of utilizable stem length in percent of tree height;
- damage (occurrence) of noxious insects, fungi, rot, and fire scars;
- number of dead trees, rough site description;
- condition of stand or recommended further treatment;
- density of stand and density in the plot (extent of unstocked area).

Measurements with relascope

Within each block 4 relascope counts are made for basal area estimation using basal area factor (baf) 2 (representing 2 square meter of basal area per ha respectively) using band 2 of the relascope. The corresponding limiting distance factor is 0.3535 m/cm of dbh for baf 2. This means that in doubtful cases the dbh must be measured with a caliper to decide whether the tree will be counted or not.

Example: baf used is 2, tree diameter (dap) = 14,2 cm. Limiting distance = 142 · 0.3535 = 5.02 m. Consequently, if the distance at breat height from plot center to tree center is 5.02 m or less the tree will be counted. If the tree is 5.03 m away from the plot center it will not be counted as sample tree.

Along the perimeter of the block 50 · 50 m, the density of trees is measured according to the transect method, i.e. the distance of open forest will be recorded as the group proceeds along the line.

Example: Plot No. 1, normal stocking 0 - 18 m, lowing stocking due to dead trees 18 - 21 m, clearing due to windbreak 21 - 25 m, normal stocking 25 - 50 m etc. All changes in stocking are recorded on magnetic tape recorder along with other noteworthy data.

Measuring of felled trees

On one sample plot of each block the three trees closest to the plot center are felled. The following measurements are taken on felled trees:

Species, dbh, diameter a mid-length, total length from foot to top, length of utilizable stem (from foot to defined top diameter) diameters of a stem disk cut from the foot and one disk from the middle of the tree, count of tree rings of both disks, measurement of bark thickness at the foot and at the center disk.

PHOTOPLOT / GROUNDPLOT PROPORTION FOR REGRESSION ESTIMATED OF TREE VARIABLES

Cost factor of aerial photo plot estimated at 1, cost of one variable radius ground plot estimated at 5 (i.e. it costs 5 times more to measure a ground plot than a photo plot).

Proportion of ground plots to aerial photo plots 1 : 5, i.e. 100 ground plots and 400 photo plots, at assumed correlation of 0.90 between tree measurements and estimates made on ground plot when compared to photo-measurements by regression analysis.

The number of photo plots can be derived from the following formula:

$$n_p = \frac{\sqrt{CV^2\ (1-r^2)\ CV^2\ r^2\ (\ c_g/c_p)} \ + \ CV^2\ r^2}{S\ \%^2}$$

CV = coefficient of variation

r = coefficient of correlation

c_p = cost of photo plots

c_g = cost of ground plots

S = standard error

For an assumed correlation $r = 0.9$ and a coefficient of variation $CV = 25$ %, and cost factor of 5, the number of stereo photo plots (n_p) is calculated as 469 to give a standard error of 1.5 % at the 95 % probability level.

This is acceptable for volume estimates since a portion of photo plots is remeasured on the ground for adjustment by regression analysis.

Cost factor n_p/n_g is calculated for an assumed correlation of $r = 0.9$ and a cost relation 1 : 5 by the following formula:

$$n_p\ /\ n_g \ = \ \sqrt{c_p\ (1-r^2)\ /\ c_g\ r^2} = 0.22$$

That means a number of $n_g = 0.22 \cdot 469 = 103$ plots are needed for terrestrial survey.

For saving inventory costs the volume coefficient of variation (s%) = 25, number of required terrestrial sample plots to achieve 1.5 % of standard error (S%) of the volume estimate:

$$N_g = s\%^2 / S\%^2 = 25^2 / 1.5^2 = 278$$

This N has to be multiplied with the cost factor ($F = n_g/n_p$) because of comparison with the calculated number of photo and ground sample plots.

For the above mentioned example a saving of inventory cost trough combined ground and photo plots amounts to:

$$[((n_g \cdot F) + n_p) / (N_g \cdot F)] - 1 = 29.5 \%.$$

The estimation of sample-plot-area percent (A%) of total area (sampling intensity) is given by the following approximation:

$$A \% = (s\%^2 \cdot S\%^2) / A(ha) = (25^2 \cdot 1.5^2) / 55{,}000 = 0.026 \%.$$

That gives a plot area of

$$55{,}000 \cdot 0.00026 = 14 \text{ ha}.$$

For the assumed accuracy by a sample plot size of 0.33 ha the number of sample plots needed for the whole area is = 14/0.33 = 422.

This value lies close to the photo plots computed for a combined inventory.

VOLUME ASSESSMENT AND RESULTS

The evaluation of large-scale aerial photographs was carried out by meansof an analog-plotting device, ZEISS Planitop F2, an interface for data transmission, ZEISS DIREC 1 and a desk computer for data registration HEWLETT-PACKARD HP 9830.

The desk computer HP 9830 can also be used as a single device for all sorts of other calculations, e.g. statistical evaluations, and works in the programm language BASIC.

At the same time, the computing system of the Federal Research Center, a PDP-11 computer, system RSX-11 m, was used for storing the data and all sorts of other evaluations, especially for multiple regression analysis.

In this case, both the data from the terrestrial inventory of pine plantations (Pinus caribaea) as well as the data from the photogrammetric measurements were stored on the RSX-11 m system. For this purpose and for various other evaluations, several short programs in FORTRAN IV language were written.

Normally, the volume of a tree is determined by the diameter at breast height (dbh), the tree height and by means of a reduction factor. During the photogrammetric measurements, however, it became abvious that a direct measurement of the dbh because of the dense young plantations from the aerial photographs not could be carried out. Therefore, a statistical relationship between the dbh and the crown diameter, a parameter very easily to be measured on aerial photographs, was looked for to get a mathematical way of assessment of dbh.

The statistic relationship was obtained by measuring the crown diameter of a number of known trees, i.e. which have also already been measured during the terrestrial inventory.

The volume was calculated from the terrestrial measurements and a correlation established between volume as dependent variable and crown diameter and dbh as independent variables. The result of a multiple regression analysis was the following volume equation:

$$v = - 0.000908 - 0.00054553 \cdot d_c + 0.00041222 \cdot dbh^2,$$

where: v = volume of single stem (in cubic meters),

dbh = diameter breast height (centimeters),

d_c = crown diameter (meters).

Multiple correlation in this case is $r^2 = 0.839$ ($r = 0.916$).

With this information all other following calculations of dbh and volume were made.

At the same time, another way of determination of the volume was tried out by establishing a correlation to the crown area ($a = (d_c/2)^2 \cdot pi$). This correlation was established in several steps:

1) average value of the terrestrial plots
2) single tree data of the photogrammetric evaluation
3) average of the photogrammetric plots.

The following results were obtained:

1) average values of the terrestrial plots: $r^2 = 0.8767$
2) single tree data, photogrammetric evaluation: $r^2 = 0.6803$
3) average values of photogrammetric plots: $r^2 = 0.9939$.

Obviously the averaging of the values for volume and crown area has an immense effect on the coefficient of determination. This effect is even enlarged in the photogrammetric evaluation by the mathematical determination of dbh and volume with the abovementioned equations.

To conclude the volume evaluations, some calculations were made to determine single tree- and stand-data in 6 different diameter classes as well as for the whole stand. The calculations were based on the photogrammetric data, the results are shown in the following table.

The best way of obtaining a stratification is the comparison of the average volume per tree and the average crown area of the different plots. If the aim of the stratification is to find out differences between age classes, it seems obvious that age must be closely correlated with both volume and crown area. If these two criteria are applied also in this case, three strata (types of plots) can be discerned.

STRATUM A average volume greater than 50.0 liters
average crown area greater than 8.5 sqm

STRATUM B volume between 20.0 and 50.0 liters
crown area between 4.0 and 8.5 sqm

STRATUM C average volume lower than 20.0 liters
crown area lower than 4.0 sqm.

To verify this stratification, two types of statistical examinations are to be carried through:

a) Examination of the correlation between stem number per hectare and volume per hectare. There should be a close correlation between these two variables inside the strata, whilst the correlation over the whole stand should be very loose (or non-existent).

b) Statistical test (t-test or Student's test) between the average of stem volume in two different strata. The same test could be made employing the average of crown area in the two strata.

EVALUATION OF THE COMBINED FOREST INVENTORY UVERITO/VENEZUELA

CALCULATION OF AVERAGE CROWN DIAMETER (IN METERS), AVERAGE DBH (IN CENTIMTS), AVERAGE STEM VOLUME (LITERS), NUMBER OF TREES PER HECTARE AND VOLUME PER HECTARE (IN CUBIC METERS) FOR 6 DIAMETER CLASSES AND THE WHOLE STAND.

	DIAMETER CLASSES						
	10.0	10.0-11.9	12.0-13.9	14.0-15.9	16.0-17.9	18.0	WHOLE STAND
AVERAGE CROWN DIAMETER	1.2	2.0	2.8	3.6	4.4	5.5	3.3
AVERAGE DBH	9.4	11.2	13.0	14.9	16.7	18.9	14.0
AVERAGE STEM VOLUME	4.98	19.37	37.31	58.51	81.42	113.91	47.64
NUMBER OF STEMS PER HECTARE	39	122	300	200	93	23	777
VOLUME PER HECTARE	0.19	2.36	11.19	11.70	7.57	2.62	37.11

The above-mentioned test is used to ascertain significant differences between the averages of two collectives of data (e.g. in this case the average of volume in Stratum A and Stratum B). For reference on t-test and t-values: cf. HUSCH, B. 1963, "Forest Mensuration and Statistics", 474 pp., Ronald Press, New York, or any other book about statistics. The tests were made between the average of Strata A and B and following results were obtained:

Correlations stem number per hectare/ volume per hectare:

Stratum A: r = 0.8349
Stratum B: r = 0.9301
Stratum C: r = 0.9993

t-test:
Following results were obtained for the average volume:

	Stratum A	Stratum B
Average	64.01	37.69
Variance	124.32	29.61
Standard deviation	11.15	5.44
Standard deviation (%)	17.4	14.4
t-value	8.955	
F-value	4.1987	

The F-value is the quotient of the variances of the two collectives of data and is used to ascertain significant differences in the distribution of the collectives around their averages.

Results obtained for the crown area per tree:

	Stratum A	Stratum B
Average	11.80	6.28
Variance	6.11	1.07
Standard deviation	2.47	1.03
Standard deviation (%)	21.0	16.5
t-value	8.64	
F-value	5.72	

In both cases, both the t- and F-values exceed the limiting values given for a probability of 99 %. It can thus be concluded that the stratification of the plantation of Pinus caribaea can be done in this way, using the information from the photogrammetric evaluation.

To conclude the stratification evaluations the percentage of the different tree classes (normal, foxtails, witchbrooms, etc.) were calculated in the whole stand as well as in the three different strata. The results are shown in the following table:

	Whole stand		Stratum A		Stratum B		Stratum C	
	N	%	N	%	N	%	N	%
Normal trees	929	86.1	426	85.0	399	84.6	105	98.1
Foxtails	58	5.4	21	4.2	35	7.4	2	1.9
Witchbrooms	73	6.8	38	7.6	36	7.6	0	0.0
Forked stems	14	1.3	12	2.4	2	0.4	0	0.0
Dead trees or broken	4	0.4	4	0.8	0	0.0	0	0.0
Total	1078	100.0	500	100.0	472	100.0	107	100.0

The table shows that the deformed trees (especially witchbrooms) are limited to the higher age classes. Mortality occurs only in the highest age class.

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RESUMEN

Durante el año 1979 se llevó a cabo un inventario combinado de bosques utilizando la fotografía aérea en grande escala y un estudio extenso del terreno en -- plantaciones de P. caribaea en la cuenca del Orinoco en Venezuela.

El equipo fotográfico consistía de - dos Hasselbad EL 500 con base fija (4.10m) y una cámara Canon de 35 mm utilizada como cámara para seguimiento del curso de - vuelo. El estudio del terreno se caracteriza por sitios patrones permanentes dentro de una agrupación (un cuadrado con un punto de relascopio en cada esquina, con una muestra de árbol seleccionada al azar y cortado para estimar su crecimiento y volumen-derivación de un estimado a base de los datos del árbol patrón). Las fotografías aéreas sirvieron también para el delineamiento de tres tipos de estructura rodal, la valoración de áreas de pastoreo defectivo, y para hacer un estimado de los defectos típicos tales como escoba de brujas y cola de zorra.

Removal Sampling of Terrestrial Vertebrates in Arid Lands[1]

R. Bruce Bury[2]

Abstract.-- A modified removal method is effective in sampling animals and indicating relative abundance. Sometimes measures of biomass and species richness are obtained. Yields of animals per unit effort are high for short durations. This is a highly cost-effective technique, but long-term studies are required to obtain detailed population data.

INTRODUCTION

Knowledge of the number of species present and their abundance is needed for environmental impact studies, comparisons of habitats, and management plans. The composition, species diversity, and size or density of populations can be determined by many methods. For example, some of the more commonly employed techniques used to determine abundance are the Schnabel method, Jolly-Seber estimators, and Peterson method (Lincoln index), all based on marking and recapture of animals (see Davis 1963, R.L. Smith 1974, M.H. Smith et al. 1975, Schultz et al. 1976, Krebs 1978, Otis et al. 1978). These techniques are widely used for research on single species. They generally require large investments of time and resources, and demand assumptions that are difficult to meet in the field.

Alternatively, the removal method is (1) more cost-efficient since each sample is taken during a short period of time, and (2) has assumptions that are more easily met. Although the removal technique provides relative values rather than absolute estimates of populations, relative estimates of wildlife are often sufficient for supporting management decision, e.g., they yield census comparisons between two habitats (control and impacted) or treatments (before-and-after). The removal technique is practical in arid lands, which are mostly open habitats with relatively homogeneous vegetation (e.g., creosote shrubland). because of these attributes, the removal method is an effective means to sample populations. This paper describes a modified version of the technique, and discusses some of its advantages and drawbacks for sampling terrestrial wildlife in arid land ecosystems.

THE REMOVAL METHOD

The rationale and development of the removal sampling technique are discussed by Hayne (1949), Zippin (1956, 1958), Grodziński et al. (1966), Delaney (1974), R.L. Smith (1974), M. H. Smith et al. (1975), and Otis et al. (1978). The removal method has been successfully employed for studies of several species of small mammals and reptiles, usually using 3-5 days of sampling. Assumptions of the technique are:

1. The population is essentially stable and stationary; i.e., births, deaths, immigration, emigration, and migration are negligible during the period of sampling.

2. The probability of capture during trapping or sampling is the same for each animal in the population.

3. The probability of capture remains constant from one sampling period to the next, e.g., sampling conditions (weather) are constant or animals do not become shy due to disturbance.

These assumptions are generally met by intensive sampling over a relatively short time. But in some situations the removal method should not be used, e.g., during migration.

The number of animals caught and removed on the first day generally exceeds the amount taken in the subsequent sampling period. The population is removed (depleted) over time. Equal or greater yields on subsequent samples

[1] Paper presented at the arid land resource inventories: developing cost-efficient methods. (La Paz, Mexico, November 30-December 6, 1980).

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indicate that one or more of the assumptions is not being met, e.g., animals are rapidly moving into the area as other individuals are removed. Usually there is an appreciable, steady decline in the number of animals obtained from one day to the next.

Linear regression is one way to estimate population size where daily captures are related to the previous number captured (Hayne 1949; Zippin 1956; M. H. Smith et al. 1975). The estimated total population is the point of intersection on the abscissa (fig. 1).

Zippin (1958) states that recapture methods (Lincoln index, etc.) are superior to the removal method in terms of the precision of estimates. But the recapture techniques usually involve more effort and cost, and are less convenient and workable than the removal method in many arid land environs.

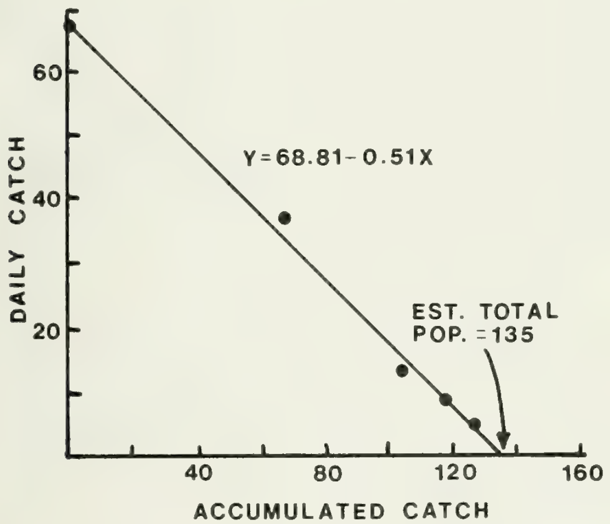

Figure 1.-- Population estimation by regression method (after Delaney 1974).

A MODIFICATION

Over the past few years, an abbreviated version of the removal method was employed to sample mammals and diurnal reptiles in the California desert (Bury et al. 1977; Bury <u>in press</u>). Sampling was conducted on only two or three days. The information proved useful for comparison of animal populations in two management areas (used and unused by off road vehicles). Species richness and diversity, abundance, and biomass measures were obtained in relatively short periods.

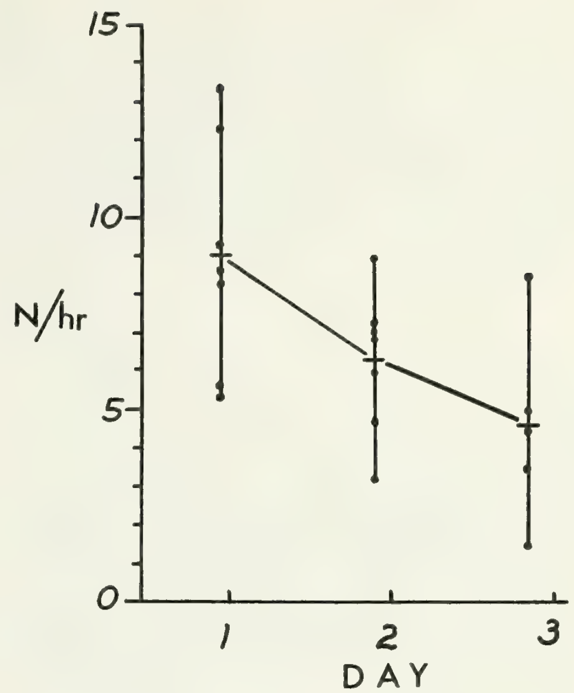

Figure 2.-- Comparison of the number of reptiles taken per hour over three consecutive days (from Bury et al. 1977).

We found a distinct decline in the numbers of diurnal reptiles taken per hour on successive days (fig. 2). There appeared to be little or no immigration onto the plot. Similarly, small mammal numbers were greatest on the first night of trapping, and less on days two and three. For both taxa, few new species and individuals were found after day two. Thus an intensive two day sample was useful for obtaining relative measures of populations in two or more plots.

FIELD PROCEDURES: A COOKBOOK APPROACH

The removal method is best carried out by killing the subjects with snap traps or weapons. It is important to sample many plots. In our surveys, we employed two sizes of quadrats and two procedures for sampling small terrestrial vertebrates. The physical arrangement and operational procedures in sampling follow.

Small Mammals

Plot size: 1 ha (100 x 100 m). Traps: 100 (75 Museum special, 25 rat) at 50 stations (2 traps per station). Trap spacing: 7 lines with 7 stations per line (12.5 m apart) and one station in center of plot. Bait: rolled oats. Sequence: 2 nights; check and reset traps each morning and evening.

The proportion of Museum special and rat traps can vary with the area to be sampled, e.g., more rat traps may be more effective where larger species such as squirrels occur. Stations are about 6 m inside the boundary (i.e., half the distance between stations). This is saturation trapping of a plot. It is also advisable to pre-bait traps before sampling.

Reptiles

Plot size: 2 ha (100 x 200 m). Removal technique: shot by .22 dust or, for small individuals, rubber bands; slow animals or protected species caught by hand or noose. Sequence: 2 persons systematically walk each plot for 3 hours on 2 successive days (6 person-hrs per ha). One person assigned to each half of the 2 ha plot; exchange sides daily to reduce collection bias.

Collecting should be performed during peak activity periods for diurnal reptiles, e.g., between 0900 and 1200 hrs from late April to early June in the southwestern U.S. and northwestern Mexico.

Documentation and Preservation

Where possible, all captured animals should be identified, sexed, and weighed in the field. We weigh small animals with spring field scales (tubular). Animals killed are prepared as museum specimens. Protected forms (e.g., tortoises) are measured and released at the place of capture.

Once an animal is trapped or killed, it is important to properly prepare and save the specimen. We routinely spend as much time in preservation and preparation of specimens as in field searches, and believe that this is worthwhile. Too often animals are misidentified and discarded in the field by personnel who do not know the fauna. This is a waste of a specimen and a loss of valuable biological information. Specimens provide voucher material for accurate identification (which for some small mammals requires laboratory examination of teeth and skulls) and add greatly to our understanding of animal systematics and distribution. Specimens are also useful for studies of reproduction and food habits, among other values.

Proper methods for skinning mammals, tagging specimens, and other techniques are provided by Hall and Kelson (1959), Hall (1962) and Williams et al. (1977). For reptiles and amphibians, Pisani (1973) provides clear instructions for preservation, measurements and data recording.

The removal method may generate large series of specimens. If it is impossible to preserve and prepare these, the removal method should not be used.

SOME DRAWBACKS

The removal technique is limited in scope and cannot be applied to all situations. Some species and habitats are difficult to sample using this method, including a few reptiles and small mammals.

Reptiles

The removal method is effective in sampling most of the species of diurnal lizards in arid land. But snakes and fossorial or crepuscular species are seldom encountered using the removal sampling procedure. To obtain a complete species list, other techniques must also be employed. These may include hand collecting (e.g., turning debris), night patrols, and pit fall traps.

Mammals

Intensive trapping for 2 days apparently provides a sample of the most common mammal species on a plot. But this technique fails to reveal certain uncommon or secretive forms such as grasshopper mice and shrews. Often 5 or more days of trapping at one site are required to capture these species. Also, the procedure does not sample bats nor the medium and large-sized mammals, which must be collected using other equipment (e.g., mist nets, large live or steel traps).

Broken or Dense Habitats

Broken terrain (such as rocky slopes and cliff faces) and dense, impenetrable habitats (such as saltcedar thickets and cactus gardens) are both unsuitable for use of the removal method because their complexity demands more time for establishing plots and for adequate sampling than our two day searches provide.

TEAM AND SCHEDULE

We use a minimum team size of three for our field work and all help to establish the mammal trap grids and reptile plots. In the early morning (0500-0600 hours), we check the traps and at least one person spends the rest of the day preparing study skins or preserving mammals in formalin after a small series of skins are made. Two people conduct the reptile surveys (usually 0900-1200 hours), and then record data and preserve specimens. New plots are established in the afternoon hours. In the evening, traps are checked and rebaited. This schedule permits intensive sampling of an area during peak times of animal abundance.

DATA ANALYSIS

The modified removal method provides a sample of animals collected at one site during a short

period of time. In arid lands, the number of species and individuals taken is usually sufficient for statistically comparisons.

Different kinds of analysis are possible. Two types of plots (e.g., natural versus impacted by human activities) can be compared simply on the basis of total species, individuals, and biomass recorded, or on derived mathematical indices of species diversity (e.g., Shannon and Weaver 1963). If adequate numbers of plots were sampled, results can be compared using the Wilcoxen Matched-Pairs Signed Ranks test (Siegel 1956). Because of the relatively fast sampling, many plots can be surveyed virtually simultaneously in one habitat. Thus features of the vertebrate population (number of species, number of individuals, biomass) can be related to habitat parameters (e.g., number of perennials, plant cover), and tested with Spearmann Rank Correlation Coefficients. Significant correlations between vertebrate population levels and habitat conditions are important intrinsically and for land management decisions. The removal method provides one way to obtain such information.

SUMMARY AND RECOMMENDATIONS

The removal method can rapidly sample vertebrate populations, particularly in open terrain. Certain groups (diurnal lizards, small mammals) in aridlands are more efficiently censused using the removal method than with other techniques such as line transects, Calhoun mammal lines, or counts of live animals. The removal method should be combined with other special techniques (e.g., pitfall traps, mist nets) to adequately reveal the diversity of species occurring in an area.

The modified removal method presented here requires only two days of intensive sampling and thus is highly cost-effective as a field procedure. Such short duration of sampling reduces the effect of possible emigration and immigration on the data. The technique is demanding when mammal and reptile populations are being surveyed at the same time, and when specimens must be preserved properly. But it yields large numbers of animals and produces valuable relative abundance data.

The method entails limitations and assumptions just as do other techniques for estimating population sizes or features. The trade-off is between the modified removal method which can rapidly indicate certain population features (e.g., relative abundance) on many sites, and other techniques of longer duration (e.g., mark-recapture) which are better estimators of population density, but usually must be restricted to one site. Where relative comparisons are adequate, the modified removal method is more cost-efficient than mark-recapture techniques. These techniques are by no means mutually exclusive. In fact, it would be valuable to use mark-recapture work as a standard against which to compare the results of the removal method.

Lastly, the removal method offers a means to sample many plots in the same time that one site could be censused in more detail, thus providing an opportunity to measure variability within a system or discover differences between habitat conditions. When properly employed, the removal method requires minimal field time and labor to obtain data of statistical, biological, and managerial importance.

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MUESTREO DE REMOCIÓN DE VERTEBRADOS TERRESTRES EN HABITATS DE ZONAS ÁRIDAS

RESUMEN

La necesidad de conocer la composición por especies, la diversidad, y la densidad de poblaciones animales es inminente. Esto, con la finalidad de realizar estudios sobre su impacto en el medio ambiente, comparar diferentes habitats y desarrollar planes de manejo. Existen varias técnicas para estimar la abundancia de la fauna silvestre en zonas áridas; muchas de ellas se relacionan con el marcaje y la recaptura de animales. Estos 2 métodos son más precisos que el método de remoción sin reemplazo, pero generalmente requieren de mayor esfuerzo y costo, siendo mas difíciles de llevar a cabo.

El método de remoción: (1:) es más eficiente en costos porque las muestras se obtienen en un corto período de tiempo, y (2:) porque las circunstancias que se suponen se cumplen facilmente en el campo. El número de animales removidos el primer día de muestreo, generalmente excede la cantidad de individuos capturados en muestras posteriores. La población disminuye con el tiempo, conforme los individuos son removidos. En reptiles y pequeños mamíferos existe poca o ninguna inmigración hacia la parcela, ya que despúes del segundo día, se capturan muy pocas especies o individuos nuevos. Por esta razón, un muestreo intensivo de 2 días, provee mediciones relativas de las poblaciones muestreadas.

La regresíón lineal puede ser empleada para estimar el tamaño de la población, graficando el número de individuos capturados diariamente, contra el número total de animales capturados. La estimación de la población total es el punto de intersección donde estas 2 variables tocan la abscisa.

Con una versíón abreviada del método de remoción, se pueden muestrear rápidamente poblaciones de pequeños mamíferos y reptiles diurnos en zonas áridas. Los muestreos se llevan a cabo por 2 o 3 días solamente. La información obtenida es útil para comparar poblaciones animales en áreas con diferente manejo. Las medidas de la diversidad, abundancia y biomasa de las especies, se obtienen en períodos de tiempo relativamente cortos.

El método de remoción sin reemplazo se lleva a cabo sacrificando a los animales capturados por medio de armas o trampas caseras (con excepción de las especies en peligro de extinción). Para ésto, es importante muestrear un número a decuado de parcelas, obteniendo datos representativos. Los animales capturados son identificados, sexados y pesados en el campo; posteriormente se preparan como especímenes de museo. Estos especímenes proveen material de referencia para una correcta identificación, estudios de ciclo reproductivo y determinación de hábitos alimenticios.

El método de remoción sirve también para muestrear rápidamente poblaciones de vertebrados (lagartos diurnos, pequeños mamíferos) en zonas áridas. El método debe ser combinada con otras técnicas especiales de captura (e.g. red de nylon, trampas hoyos) para revelar de una manera mas precisa la diversidad de especies del área de estudio. Al igual que otros métodos para determinar el tamaño de la población, la remoción sin reemplazo tiene sus limitantes y asunciones. La elección es entre: el método de remoción, que nos puede indicar rápidamente características de la población, en muchos sitios (como abundancia relativa), y otras técnicas (como marcado y recaptura), que son mejores estimadores de la densidad de la población, pero requieren de más esfuerzo y generalmente se restringen a un solo sitio.

Para ser efectivo, el método de rémocion requiere de intenso trabajo de campo. Cuando se emplea correctamente, este método permite al equipo de trabajo salir adelante y muestrear tantas parcelas como sean necesarias para obtener datos de importancia biológica, estadística y de manejo.

Measurement Techniques in the Pinyon-Juniper Woodlands of Nevada[1]

Harry T. Rhea and John W. McGlothlin[2]

Simple and effective inventory techniques are needed to assess arid zone woodland resources. One such method has been developed by the U.S. Forest Service, USDA, and the Bureau of Land Management USDI, for use in the Pinyon-Juniper woodlands of Nevada. This method employs one-tenth acre ($405m^2$) premanent plots located on the Universal Transverse Mercator (UTM) grid.

INTRODUCTION

Many tree species in arid and semi-arid zones have unusual or unique growth forms. Simple and efficient methods must be devised for the measurement of these species. Any such system should permit the development of volume equations and analysis of various components of volume prediction. After determining which elements correlate closely with volume, future measurements may be limited to these elements. This paper describes one such system used in the pinyon-juniper woodlands of Nevada. This system was developed as a cooperative effort of the Bureau of Land Management in Nevada; the US Forest Service, Intermountain Forest and Range Experiment Station, Renewable Resource Evaluation unit at Ogden, Utah and Bureau of Land Management Personnel at the Denver Federal Service Center.

The woodland resources in semi-arid and arid zones are very important, particularly in developing areas where the use of wood for fuel is high. In this era of scarce resources there is a need for careful management of these lands. Proper management requires a data base. However, the limited economic value of woodland species and the scattered occurence of stands, coupled with the ever-present budget limitations, have given inventory of woodlands a low priority in the past.

PAST INVENTORIES

Some efforts were made in the mid-1960's toward developing inventory systems for Pinyon-Juniper in Nevada. For the most part, these inventories were concerned with making an estimate of area and mapping, with stand density and volume being secondary considerations. In other areas, notably Arizona and New Mixico, efforts have been made to develop volume tables and equations for the woodland species.[3,4]

Problems in Data Collection and Compilation

Computer processing has now evolved to the point where there are innumerable "canned" programs for dealing with the mass of data used in forest management. There are also field forms for collecting data in the coded formats used by these programs. However, these programs and forms are designed for commercial species. While there are some local and some general volume tables available, these tables are for _Pinus edulis_ and _Juniperus scopulorum._ Throughout Nevada, _Pinus monophylla_ and _Juniperus osteosperma_ predominate.

Adapting Extensive Forest Inventory Techniques

The growth form of Pinyon, and particularly of Juniper, is so irregular and multistemmed that the traditional DBH-hight-volume relationship is skewed. The hight limit for these species is generally short; twenty-five to thirty five feet (7.67m. to 10.75m) is the normal range in an old stand. They exhibit large crown spread, and are more variable in density and shape than other members of their respective genera.

From the available literature, it appears that crown volume provides better correlation with wood volume than the traditional diameter-height relationship.

AN EXAMPLE - EASTERN NEVADA

Between 1978 and 1980, an extensive inventory was conducted on the Ely District of the Bureau of Land Management. Of the 8 million acres (3,237,485 ha.) in the district, 2,476,326 acres (1,002,148 ha.) are woodland or forest. This is divided into two management areas of approximately equal size.

In general, the standard techniques of a typical extensive inventory were used. The plots were chosen on a fixed grid using the even 5,000 meter intersections on the Universal Transverse

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[1]Presented at the Arid Land Inventories Workshop, La Paz, Mexico. November 30-December, 1980.

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Mercator (UTM) system. Plots were then located on small scale (1:24000) maps and air photos to facilitate field location.

Because of highly variable stand densities, irregular tree form, and the need for a reasonably large sample of trees for volume determination, a fixed plot, .1 acre (405 m^2) in size, was chosen. A circular shape was considered best for ease of establishment and determination of on-plot trees. The route to each plot was recorded on mylar overlays for each of the aerial photos, and marked on the ground with painted markers at strategic points. A written description of the route was filed with the plot data. Plot center was located with a hand compass and 100 foot (30M) cloth tape, using distance and direction calculated from map and photo data. Plot center was marked with an iron or wood post surrounded by a rock cairn. Plot was then referenced by azimuth and distance to two blazed and painted witness trees.

Tree Measurements

After the plot was established and described as to slope, vegetation, land form and elevation, tree measurements were taken. The characteristics of each tree measured were maximum and minimum crown diameter; diameter at the root collar (DRC) and total height. The number of stems and the number of 3 inch forks were counted, and the number of juniper posts or the pinyon Christmas tree grade were recorded for each tree. Each tree was numbered with an aluminum tag placed at the point of diameter measurement.

In addition, three trees of each species were visually divided into segments whose length were estimated in two-foot classes; mid-point diameter was also estimated. These measurements were then recorded for volume calculation.

The important point here is that all measurements were reasonably simple and related directly to volume determination. The DRC measuremant was somewhat unusual, in that diameter measurements are usually at breast height (4.5 ft./1.5 m) or stump height (1 ft./25 cm). The Juniperus osteosperma frequently forks below this point and yet forms a single crown if viewed from above. Therefore, if each stem were treated as a separate tree, aerial volume estimates would be difficult.

These tree characteristics gave a fair correlation with volume, and were used through 1979 on one management area. However, random checks showed that taking the geometric mean of the individual stem diameter rather than taking one measurement would result in more accurate data. This system was tried during the 1980 field season, and will be compared with the results of some destructive sampling conducted adjacent to slected plots. In order to check the accuracy of the visual segmentation, trees around these plots were segmented and then cut and measured. The results of this check have yet to be completely tabulated, but look promising.

Field Crews and Cost

It was found that a two-person crew could efficiently collect the necessary data. With long distances between plots one, or at best two, plots per day per crew could be expected.

The crews were temporary employees, with limited experience. However, a week was found to be sufficient for training and familiarizing them with the procedures and forms. Frequent checks were made to assure consistency and accuracy of measurement and estimation.

The equipment needed is simple and relatively inexpensive, the most complicated item being an Abney level.

Transportation proved to be the most expensive item, but this was minimized by camping near groups of plots. Considering the product value and intensity of management, the cost was not prohibitive.

In summary when inventorying low value woodlands, there is a need for coordination, as different agencies often need the same data. Costs can be reduced by taking only necessary data and by keeping methods as simple and direct as possible. We must, however, remain open and flexible, changing methods as species, product, and data needs change, keeping in mind the constraints of area, time and allowable cost.

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[3] Clendenen, Garry W. "Gross Cubic Volume Equations and Tables, Outside Bark, for Pinyon and Juniper Trees in Northern New Mexico". USDA-Forest Service Research Paper INT-228. 1979.

[4] Moessner, Karl E. "Preliminary Aerial Volume Tables For Pinyon-Juniper Stands" USDA-Forest Service Research Paper No. 69. 1962.

RESUMEN

Para evaluar los recursos de bosques en zonas áridas se necesitan métodos simples y efectivos de inventario. Un método tal ha sido desarrollado por el Servicio Forestal de E.U., USDA y por el Negociado de Manejo de Tierras, USDA, para ser utilizado en los bosques de Piñon-Junípero de Nevada. Este método utiliza un décimo de acre (405 m^2) de sitios permanentes localizados en el tendido Universal Transverse Mercator (UTM). La mensuración de los árboles provee la data para estimar el volumen en pies cúbicos y el número de productos por acre (.405 ha) al igual que para calcular el volumen por medio de una ecuación, y para la construcción de una tabla. Los datos fisiográficos obtenidos permiten la clasificación de los sitios. La utilización de este método en el distrito de Ely, USDI-BLM indica que éste es efectivo en costo y que es una forma eficiente para obtener datos extensivos de inventario en zonas arboladas áridas.

Measurement Techniques for Inventorying Riparian Systems[1]

Richard E. Warner[2] and Edwin F. Katibah[3]

Abstract. --Arid land riparian systems are often small in area but of extreme ecological and economic value. Their abusive overuse is widespread and growing. Many systems have been or are being destroyed. This disruption complicates inventory processes. Because of their unique physical, vegetational, and ecological characteristics special inventory methods and emphases are suggested. Insights developed from an integrated remote sensing/groundbased riparian inventory of the Central Valley, California, are presented. Vegetation structure and floristics were both used to estimate condition.

INTRODUCTION

Despite their nearly universal distribution and immense economic and ecologic values, riparian systems have until recently remained largely ignored and unmanaged as a global resource. Because of this neglect, study of their structure and function is only now underway, and the results of extensive human use impacts remain largely unmeasured.

This paper reports on the special problems associated with inventory of riparian systems. It draws upon experience gained in an integrated remote sensing/groundbased inventory of riparian systems in the Central Valley of California during the summer of 1980. While the study itself is regional, efforts are made to generalize in order to make the findings more globally applicable. With appropriate modification of mapping categories, vegetation descriptors, and riparian utilizing bird species, the methodology described should be amenable to arid and semiarid systems anywhere.

BACKGROUND CONSIDERATIONS

Successful application of any inventory methodology to riparian systems requires an understanding of the their general properties. Because this understanding is still evolving, it is useful to briefly examine the nature and structure of the systems before detailing methodological protocols.

Riparian Systems Defined And Described

Riparian (adj., from the Latin Ripus, bank; as of a river): pertaining to the banks and other adjacent terrestrial environs of watercourses, freshwater bodies, and surface-emergent aquifers whose transported waters provide soil moisture in excess of that otherwise available locally, sufficient to support a mesic (moist soil dependent) vegetation distinct in structure and/or floristics from that of the contiguous and more xeric (arid) uplands. (Warner 1979)

Stated descriptively, riparian systems are the aggregations of mesic terrestrial vegetation, dependent faunation or animal life, and local environment (e.g. microclimate) supported by the following terrestrial, moist soil substrates: a)perennial and intermittent river and stream banks; b) floodplains and overflow terraces; c) springs, seeps and wet meadows; d)desert washes, playas, and wadis; e) desert oases; f)vernal pools; g) lake, pond, marsh, and reservoir edges; h)wet tundra; and i) unlined ditches and drainageways.

In arid regions of North and Central America common indigenous riparian trees include cottonwoods and aspens (*Populus* spp.), willows (*Salix* spp.), alders (*Alnus* spp.), sycamores (*Platanus* spp.), palms (*Washingtonia* spp.), mesquites (*Prosopis* spp.), and others. Associated with these mesic trees is a host of mesic understory, shrubcover, and groundcover species. Both structure and floristics of the systems are molded by the broadly regional and temporal dimensions of climate, geomorphology, topography, and biogeography. Extremely arid systems typically lack the canopy producing tree species listed above, and the associated multilayered vegetation structure. In those systems acacias (*Acacia* spp.), lysiloma (*Lysiloma* sp.) paloverde (*Cercidium* spp.) and other more tropical xeric species may be the dominants.

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[1]Paper prepared for conference Arid Land Resource Inventories: Developing Cost-Efficient Methods; An International Workshop (La Paz, Mexico, November 30 - December 6, 1980).

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Size, Extent, And Configuration

Riparian systems vary in size from broad, extensive floodplains to springs and seeps a meter or two in diameter. Overall, they comprise a very small part of any land area. In addition, they are often extremely narrow and intensely linear in configuration, transecting large zones of otherwise arid upland. Zonal land inventory methods have typically tended to ignore them, and thus to understate or omit their ecotonal and other structural and functional relationships to both the associated biota and the zonal uplands. Because of this small individual size, satellite imagery - where pixil size usually exceeds 0.5 hectare - and even U-2 and optical bar imagery, which is generally in the 1:80,000 to 1:35,000 range, has been found to be of only limited use. We have found that aerial imagery of 1:6,000 is the most useful for detailed inventory work.

Many riparian systems have closed or partially closed canopies, further limiting application of otherwise valuable remote sensing techniques. Because data on the structure, floristics, associated animal life, and the conditions of understory, shrubcover, and groundcover components of the systems are generally required, site-specific groundlevel studies are an essential component of any detailed riparian system inventory.

Ecological And Economic Values

Despite their generally small individual size and total extent, the ecological values of riparian systems are extreme, especially in arid lands. With reference to the United States the U.S. Council on Environmental Quality recently stated:

"No ecosystem is more essential to the survival of the nation's fish and wildlife. For example, western riparian ecosystems contain approximately 42 percent of the mammal species of North America, 38 percent of the reptiles, and 14 percent of the amphibians (J.P. Hubbard, 1977). Seventy-seven percent of the breeding birds (R.R. Johnson, et al., 1977) and 75 species of fish of the Southwest are dependent upon riparian ecosystems (J.P Hubbard, 1977)." (U.S. Council on Environmental Quality 1978)

Similarly, the economic values of riparian systems are often extreme. They have since before recorded history been the preferred sites of habitation, agriculture, and other intensive human use practices. Thus, in the planning for and design of any riparian inventory, recognition of these high values should be reflected in the allocation of inventory resources to assure that sufficient attention is paid them.

Impacts And Loss

Destruction and loss of riparian system ecologic and economic productivity through misuse and neglect are global, chronic, and accelerating. Centuries of human settlement in and selective unregulated use have tended to reduce them in both size and structural complexity. In some instances the indigenous vegetation has been completely replaced, either with cultivars, with browse resistent species, or with bare ground. This problem is exacerbated in arid regions, where riparian systems are simultaneously inherently more vulnerable to structural and floristic damage, and subjected to greater dry season use pressures. Such pressures often become catastrophic during periods of extended drouth.

This point has special relevance to inventory methodology, especially in those areas where much or most of the indigenous riparian vegetation has been removed. In those cases it is often impossible to discern the extent of the riparian zone if the inventory methodology relies exclusively upon vegetation parameters. Delineation of these occult (occult: concealed, hidden from view) zones using remnant vegetation, topographic, soil type, and other clues is essential in the determination both of their potential extent and their restoration possibilities through management.

Remote Source Damage Vulnerability

Virtually all riparian systems are dependent upon water (and often nutrients, soil, and hydraulic energy) supplied from a remote source. Thus, improvident manipulations of the remotely originating elements can have profound effects upon distant riparian systems. Disruption of watershed vegetation through overgrazing; damming of watercourses and/or diversion of streamflow; lowering of aquifer levels through excessive pumping; channelization and levee construction on watercourses; can all cause significant and often disruptive changes in riparian systems.

It is important that to the greatest extent possible these direct and indirect hydrologic perturbations be encompassed in the design of riparian system inventories. Neglecting them can lead to inventory results which are incomplete or enigmatic. In our Central Valley studies, we have found such remote manipulations to be a major cause of change in the distribution, structure, and floristics of riparian vegetation, exceeded only by the complete displacement resulting from cultivation agriculture.

CALIFORNIA RIPARIAN STUDY PROGRAM

Program Objectives

A brief examination of the California Riparian Study Program is useful, to illustrate the level of field effort and sampling intensity for which the present methodology was designed. The overall goal of the Program, which is being administered by the California Department of Fish and Game, is: "To protect, improve, and restore the riparian resources of the state." Specific Program objectives are:

"1. To determine historical extent of the riparian resource in Central Valley and Desert and the causes of its destruction.

2. To determine the present status of the riparian resource.

3. To identify problems and threats to resource maintenance.

4. To recommend measures for riparian resource protection, improvement, and restoration." (Warner 1979).

No previous studies of the state's riparian resources had ever been conducted within such a comprehensive frame of reference. Available data are extremely limited, and are primarily site-specific ecological treatments of zoological or botanical questions. A few studies, such as those of McGill (1975, 1979) had quantified changes in riparian system extent over time, but for only limited portions of the study area. Thus one Program study need was for an extensive inventory which would provide a comprehensive statement of present distribution, condition, and condition trends of all riparian systems in the study area. This need was addressed through development and application of the inventory methodology described below, which was designed primarilty to satisfy objectives 2,3, and 4. Other techniques were used to quantify the presumptive primeval extent of riparian system distribution, and are being reported elsewhere (Katibah and Warner in press)

The Study Area

The Central Valley of California is a great trough extending in a northwesterly direction from its southern end for some 830 km (500 mi). Its width averages 158 km (100 mi). It is bounded on the east by the Sierra Nevada Ranges and on the west by the Coast Ranges. It is comprised of two major geomorphic systems: a) the largely unconsolidated depositional materials comprising the valley floor, and b) the largely consolidated sedimentary and metamorphic rock of the surrounding mountain ranges. Climate ranges from very arid in the south to arid in the north. Numerous perennial and intermittent rivers and streams transect the lower foothills and valley floor, having originated in the bounding mountain watersheds. Two large rivers (the Sacramento and San Joaquin) collect these waters and transport them respectively south and north to San Francisco Bay. An extensive system of dams and diversion systems has greatly modified natural patterns of water flow. Cultivated agriculture has displaced several hundred thousand acres of indigenous riparian forest. Groundwater pumping has lowered water tables in major aquifers, especially in the south. Livestock grazing in the foothills has reduced and simplified riparian vegetation along smaller streams and sloughs.

EXTENSIVE INVENTORY DESIGN

Inventory Needs

Principal inventory needs included: a) location; b) areal and linear extent; c) vegetation structure and floristics; d) vegetation condition and condittion trends; e)streambank condition; f)kinds and extents of intrasystem use; g) adjacent land uses; h)species richness and distribution of riparian dependent birds; i) effects of channelization and other hydrologic manipulations; j)other discernible threats to the resource; and k) potentials for restoration both to vegetated and occult zones.

Although the California Desert is part of the overall Program study area, the USDI Bureau of Land Management, through its California Desert Plan Program, had underway studies which to some extent embraced riparian systems in that area. It was therefore concluded to omit the desert from the present field study, and to utilize data obtained from the BLM program. However, the present inventory methodology was developed for application in the desert as well as the Central Valley, should that ultimately prove desirable.

Design Constraints

Three major a priori constraints, all of them universal, were imposed on the Program. First, the total sum available for the inventory was approximately $65,000. Second, time available was limited for the fieldwork to the interval March through July, 1980, during which period design, testing, and execution of the field aspect of the inventory had to be completed. Third, the area to be encompassed by the inventory was approximately 131,000 square kilometers (50,000 square miles).

Additonal functional constraints included: a) the need for high resolution aerial photography; b) the need for qualitative and quantiative site-specific ground studies; c) lack of available data on intra-and inter-tract structural and biological diversity; and d) logistical demands deriving from study area size.

With respect to imagery resolution, the National Wetland Inventory has demonstrated that with 1:60,000 color infrared photography it can map units as small as 0.04 ha (0.1 acre) with reasonable confidence (Nyc 1980). However, detail is insufficient for identification of specific mapping categories (discussed below) or for other site-specific data such as condition and use. One implication of this constraint is that the otherwise very valuable Federal High Altitude Aerial Photography Data Base Program, established in 1979 to provide a 1:80,000 black and white and 1:60,000 color infrared aerial photography master set for the United States, is of only limited use for riparian system studies.

With respect to the extremely limited data base on the structure and floristics of riparian systems generally, one important and immediate constraint effect is that traditional parametric statistics cannot be used with any confidence, since intratract and intertract variances are unknown. These systems are known to be highly variable and to some extent individually unique, owing to the geomorphic, hydrologic and other variables responsible for their formation. The use of nonparametric statistics (e.g. Lehmann 1975) is preferred, a strategy which also permits greater latitude in experimental design.

Classification Systems Vs. Mapping Categories

An analysis of available vegetation and ecological classification systems applicable to the Central Valley (Warner 1979) had concluded the Brown et al (1980) system to be most suitable. However, because a riparian mapping program for much of the study area had just recently been completed using a mapping category scheme (Calif. State Univ., Chico and Calif. State Univ., Fresno 1979) initially developed by McGill (1975) for the Sacramento River, that scheme was used instead of Brown et al (ibid).

In contrast to a classification system, which permits universalization of data and facilitates ecological interpretations of findings, a mapping category scheme is essentially an empirical statement of the structural or physiognomic character of the vegetation, in this case as discerned from aerial photography. Its principal value in the present instance is that it permitted use of the riparian maps and their associated data on areal and linear extent.

To somewhat offset the limitations of the mapping category scheme and to work toward the application of classification system, each tract was assigned a "heliophyte covertype" designation. The heliophyte covertype system is one presently under development for the California Department of Fish and Game by The Nature Conservancy (Holstein, personal communication) as part of the California Natural Diversity Data Base Program. It utilizes a classification protocol based on the dominant plant species exposed to the sun (heliophyte). It is approximately equivalent to the sixth level (distinct plant associations) of Brown et al (ibid), or perhaps more accurately between Brown et al's sixth and seventh levels.

Mapping Categories Utilized

The following riparian mapping categories were utilized in the present study:

- R1 large woody vegetation
- R1v valley oak woodlands
- R2 low woody vegetation
- R3 herbaceous vegetation
- R3p herbaceous perennial seeps and springs
- M marsh
- S sand and gravel bars
- A agricultural land
- U urban land

Modifiers for major mapping categories included the following:

- c channelized
- d disturbed
- i intermittent.

Hybrid classes were formed as required (e.g. R1/R2), based on conventions established for dominance and multiple class reporting.

Stratification

To address intertract variance within the study area, sequential stratification based on climatic, geophysical, land use, and available riparian data parameters was employed as follows:

1. climatic
    - 1.1. north valley
    - 1.2. south valley
2. geophysical
    - 2.1. coastal foothill
    - 2.2. Sierran foothill
    - 2.3. depositional flatland
3. land use
    - 3.1. irrigated agriculture
    - 3.2. dryland agriculture
    - 3.3. non-agriculture (incl. rangeland)
4. available riparian data
    - 4.1. mapped
    - 4.2. unmapped

A total of 39 strata were identified by this process, to which 168 sample sites were allocated on the basis of relative area of each stratum. It was, however, recognized at the outset that the small number of total sites available (168) precluded the use of statistical comparisons for many inter-strata differences, and that some lumping was inevitable.

Selection of sample sites was done using a randomization protocol which first selected a 7½' quad map, then one gridded square on that quad, and finally a specific riparian tract. Randomly selected tracts or sample sites were rejected if they were logistically impossible or otherwise completely unsuitable and replaced with another randomized sample site.

Nonrandom Sample Sites

It was felt important that riparian systems of special importance be included in the inventory. These included those known to be unique, to be relatively intact, and/or of special ecological importance. A subset of 20 nonrandom sites was selected based on available information and recommendations of field scientists with local knowledge. This subset was included in all inventory field studies but was excluded from analyses requiring randomization of sample sites. Because some of the nonrandom sites were relatively intact (there are no pristine riparian systems left in California) they serve as quasi-controls and as best available baselines for comparative purposes.

Allocation Of Resources

Budget constraints limited the number of field days to 80. These were alloted as follows:

1. 60 days of intensive ground data acquisition;
2. 8 days for aerial photographic data acquisition;
3. 12 days for extensive ground data gathering;
4. remainder of budget devoted to data analysis and preparation of final report. Methodology development and testing was included in 1-3 above.

Ground Inventory Methodology

Field Team Deployment

The field team consisted of a senior scientist team leader plus one field assistant. The team was equipped with a 20 foot recreational vehicle which permitted on-site camping the night prior to a tract inventory. Field activities were broken into 10 day blocks, during which 10 tracts were inventoried. After a 4-5 day break, an additional 10 day field period ensued. A typical daily schedule was as follows:

1. hike to tract at first light;
2. inventory until approximately 13:00;
3. return to vehicles and drive to next tract;
4. contact landowner to arrange trespass;
5. briefly survey tract and camp for night.

This procedure required on average 12 hours per day. It was found that for complex or logistically difficult systems one day was insufficient. Two days per tract would permit more detailed and in depth study, and is recommended if funds permit, the systems are at all complex, and/or if additional study parameters are added. Increasing team size to three or four would permit adequate one day tract inventories for all systems.

Data Collection Procedures

Space limitations obviate detailed descriptions of either the ground or remote sensing procedures. Figure 1 illustrates the data entry descriptors used on the three forms developed for field use. A 2 meter pole marked off in decimeters was used to quantify groundcover and shrubcover vegetation height. Cross sectional transects were run across the system, from upland to upland if the watercourse was negotiable, from upland to watercourse if not. Vegetation data (Form A) was recorded outbound, DBH data (Form B) recorded inbound. Vegetation height and floristics were recorded at each 3 meters along the transect. DBH data were recorded in a 3 meter swath along the same transect line. Bird observations were made while moving slowly through the tract, with locations recorded in meters up- or downstream from a recorded Tract 0 (starting) Point, selected on the basis of permanence and visibility to aerial photography. Groundcover and shrubcover were measured in decimeters; understory (considered present only if a canopy was also present) bottom and top heights were estimated in meters; canopy bottom and top heights were estimated in meters by triangulation. Unknown species were collected for later identification. Stem size (DBH) of woody species with stems greater than 2 cm was measured optically by holding a meter rule at arm's length against the stem and alligning the 0 end at left stem edge. The observed diameter was recorded in millimeters and later converted to actual diameter by a conversion equation. Very large trees were measured circumferencially with a metal tape and the readings converted to DBH. Figure 2 is the descriptor code list for the vegetation form. Standard IBM forms were used.

FORM A VEGETATION

- Data Type
- Day
- Month
- Investigator
- Tract Number
- Distance From Tract 0 pt. (m)
- Direction
- Transect Type
- Adj. Veg. Type
- Adj. Land Use
- Transect Pt. No.
- Groundcvr. Type
- Gdcvr. Ht. (dm)
- Shrubcvr. Type
- Shrubcvr. Ht.(dm
- Understory Type
- Understory X Height (m)
- Understory Est. % Cover
- Canopy Bottom Height (m)
- Canopy Top Height (m)
- Streambank Cond.
- Orientation (L,R
- Trans. Dir.(P,R)
- Distance From Line (m)
- Uses Impacting Riparian System

FORM B DBH

- Data Type
- Day
- Month
- Investigator
- Tract Number
- Distance From Tract 0 Point (m)
- Direction
- Transect Type
- Vegetative Transect Pt. No.
- DBH
- Species
- DBH
- Species
- DBH
- Species
- DBH
- Species
- Orientation (L..
- Distance From Survey Line (m)
- Trans. Dir. (P,R)
- DBH Metrication

FORM C BIRD

- Data Type
- Day
- Month
- Investigator
- Tract Number
- Direction
- Bird Species
- Perch Substrate
- Perch Height
- Time
- Wtrcse. Status
- Distance From Tract 0 Pt. (m)
- Distance From Upland Edge (m)
- Distance From Watercourse (m)
- Total Riparian System Width (m)
- Association/ Cover Type
- Orientation (L,R)
- Distance From Survey Line (m)

Figure 1.--Entry descriptors for Vegetation, DBH, and Bird field data forms.

CALIFORNIA CENTRAL VALLEY RIPARIAN PROJECT

VEGETATION TRANSECT SURVEY FORM: 1980 (DATA TYPE A)

Data Entry Descriptor Code

6. Investigator
   - D. Dummer
   - W. Warner
   - A. ______
   - B. ______

13. Direction
   - U. Upstream
   - D. Downstream

14. Transect Type
   - A. 3 m Transverse
   - B. 20x20m/3m Bird
   - C. ______
   - D. ______

15. Adjacent Vegetation Association/Cover Type (See List)

16, Adjacent Land Use
36.
   - A. Undevel. Wildland
   - B. Open Range Grazing
   - C. Fenced Range Grazing
   - D. Irrigated Pasture
   - E. Dry Farming
   - F. Irrigated Row Crops
   - G. Irrigated Orchard
   - H. Urban/Industrial
   - I. Suburban Housing
   - J. Commercial Forestry
   - K. Forestry/Grazing
   - L. Small Acreage Homesite
   - M. ______
   - N. ______
   - O. ______
   - P. ______

19. Groundcover Type
   - A. Bare Ground
   - B. Leafy Litter
   - C. Woody Litter
   - D. Grass
   - E. Forbs
   - F. Berries
   - G. Shrubs
   - H. Road
   - I. Water
   - J. Cattails
   - K. Sedges
   - L. Water/Veg.
   - M. Rushes
   - N. ______
   - O. ______
   - P. ______
   - Q. ______
   - R. ______

22, Shrubcover/understory
25. Type
   - A. Sambucus sp. (Elderberry)
   - B. Salix sp. (Willow)
   - C. Baccharis sp. (Coyote Bush)
   - D. Eriogonum sp. (Buckwheat)
   - E. Tamarix sp. (Tamarisk)
   - F. Acer negundo (Box Elder)
   - G. Rhus diversiloba (P. Oak)
   - H. Rubus v. (Blackberry)
   - I. Rosa c. (Wild Rose)
   - J. Vitis c. (Wild Grape)
   - K. Cephalanthus sp. (Buttonbush)
   - L. Nicotiana g. (Tree Tobacco)
   - M. Arctostaphylos sp. (Manzanita)
   - N. Alnus sp. (Alder)
   - O. Cornus s. (Creek Dogwood)
   - P. Umbellularia c. (Calif. Bay)
   - Q. Quercus lobata (Valley Oak)
   - R. Quercus douglasii (Blue Oak)
   - S. Quercus dumosa (Scrub Oak)
   - T. Quercus sp. (Oak sp.)
   - U. Heteromeles a. (Toyon)
   - V. ______

22, Shrubcover/Understory
25. Type (Continued)
   - W. ______
   - X. ______
   - Y. ______
   - Z. ______

34. Streambank Condition
   - A. Eroded/Bare
   - B. Intermediate
   - C. Vegetated/Stable
   - D. Not Applicable

39- Present Impacting Uses
40. On Riparian System (See List)

Figure 2.--Entry descriptor code for vegetation form. Descriptor codes were included on all field data forms (8½"x14" overall).

Because of special interest in the question of riparian system dependency and use by certain bird species, two 20 meter vegetation transects (13 transect points where point 7 fell at the site of observation) were run, one at a right (90°) angle to the other. These data were treated separately from the standard vegetation transect data. All bird species observed were recorded, but only a selected list of "riparian preferring" and "riparian frequenting" birds, derived from a review of the scanty literature, was treated as described above. In simple and highly degraded riparian systems bird species richness was determined. In large, complex systems time and field staff limitations precluded such determinations, although most species were located. Recommended procedure for bird species richness determinations, based on present experience and unpublished data (Jerry Verner, personal communication) would be the following:

1. divide observational activities into delineated time periods (e.g. 1 hour each);
2. replicate observational periods using all competent field staff;
3. record all replicates separately;
4. plot cumulative species location scores as a function of total observation period replicates;
5. resulting curve will flatten as tract species richness is reached;
6. 10-12 replicates should be sufficient for 80+ percent species richness;
7. additional replicates can be run, time and staff permitting, for total species richness, until cumulative species richness curve reaches asymtote on graph.

The total list of structural, floristic, locational, condition, and use parameters either quantified or qualitatively estimated can be discerned from study of figures 1 and 2. The parameters will not be discussed individually, as some are self evident and in any case a project-specific set will need to be generated because of differing objectives and types of riparian systems studied. The general design of the field form, with data entry columns at left and relevant descriptor code at right, proved highly successful and is recommended. With respect to figure 1, note that the entry descriptor lists have been turned 90° to facilitate study. Entry columns are normally vertical, as per standard IBM forms.

Descriptive Statistics

A principal objective of the field measurements was to provide a quantitative basis for determining riparian tract structure and for intertract comparisons. A second major objective was to determine the condition of tracts, with respect to human use impacts. The methodology described above, where groundcover, shrubcover, understory, and canopy components of the vegetation were quantified by height, provided the structural data. Ancillary observations on streambank condition, adjacent land use, etc., augmented the structural data. Not enough is known about the floristics of riparian systems of the Central Valley to use them comparatively for condition estimators. However, the distribution, abundance, size and age, presence or absence of reproduction, and condition of indigenous riparian trees and other perennial woody vegetation are all useful indicators of cumulative human use impacts and restorational potential for the systems. These features were recorded, and should be recorded in any inventory.

Simple descriptive statistics presently being tested and which are proving useful for characterizing riparian tract structure are the following:

1. mean height by covertype (incl. standard deviation and variance);
2. percent occurence by covertype;
3. interspersion index by covertype (frequency with which one covertype is followed by another covertype on sequential transect points);
4. tract interspersion index;
5. percent contribution by height of covertype;

Note: "covertype" as used here means bare ground, leafy litter, etc. for groundcover (see 19., fig. 2), _Sambucus sp_. etc. for shrubcover (see 22,25, fig. 2) and so forth.

Other descriptive statistics based on both structure and floristics are presently being developed and tested. So little work has been done to date on the classification and characterization of riparian systems that the present effort is considered exploratory. The traditional assumptions of intratract structural and floristic homogeneity which have prompted the uncritical use of parametric statistics are clearly called into quesiton by our field observations and preliminary analyses.

Analytical Statistics

Two procedures are presently under study. The Shannon diversity index (Pileou 1975) is being applied to vegetation floristics and structure for intertract comparisons. The determination of diversity requires both species richness and density. Since quantifying avian species densities was out of the question, owing to the many field problems associated with that exercise, intertract avian diversity comparisons will not be made. Indeed, so unreliable are most avian density estimates that comparative studies based on species richness and relative abundance are recommended instead as a general practice for extensive inventories.

The use of Euclidean distance (Orloci 1975) and Chord distance (Orloci 1975) are also being studied. These two tests demonstrate possible ecological distances (i.e. differences) between tracts, in this case using floristic and structural criteria. Nonparametric tests of significance (Lehmann 1975) will be employed. (See also Newbold _et al_ 1980).

Other Parameters

A variety of other field measurements is possible within the general format described above. The selection of specific procedures will depend

upon the following:

1. overall goal and specific objectives of the inventory;
2. time and funds available;
3. training and experience of field staff;
4. nature of riparian systems being studied.

Such measurements could include, for example:

1. censuses of vertebrate populations;
2. browse utilization by covertype and/or species;
3. pellet group counts;
4. crown density;
5. foliage volume;
6. groundcover taxa;
7. direct utilization (e.g. fuelwood).

Standard procedures are available for these and other vegetation, animal, and impact parameters. Because this paper is devoted to methodology, no attempt will be made to review the more indepth ecological studies which have been made utilizing inventory data. Attention is called to Johnson and Jones 1977, Graul and Bissell 1978, and Johnson and McCormick 1978 for useful entries into the relevant literature.

Remote Sensing Inventory Methodology

Data Collection Procedures

Aerial photography of the 168 sample sites was undertaken during June and July, 1980, during the period of fully leafed canopy. Photo flights were flown up or down the riparian system using 7½' quad maps for reference. True color film was used rather than infrared because it was found easier to interpret, owing to the direct correlation between onground visual observations and remote sensing imagery. This permitted a significant reduction in photo-interpretation time. Cameras were mounted over a belly aperature in the aircraft, on true vertical mounts with tip and crab correction controls. Technical data are as follows:

1. aircraft: Cessna 185;
2. camera: Hasselblad ELM (motor drive);
3. lens: 100mm Zeiss f3.5 planar;
4. film: Ektachrome MS, Type 2448 (natural color transparency, 70 images/magazine);
5. height: 600m above ground;
6. scale: 1:6,000;
7. sequence control: manual start intervalometer set to provide 60 percent forward overlap;
8. shutter speed: 1/500 second;
9. filter: UV, for lens protection only.

Photo-interpretation Procedures

A hierarchical interpretation scheme was used, where a) streambank; b) riparian zone; and c) adjacent upland were examined for the following parameters as relevant:

1. stream and streambank condition;
2. groundcover (where visible);
3. shrubcover vegetation;
4. overstory/canopy vegetation and structure;
5. direct and indirect human use.

Final analysis is compiled in the following form, both by tract (sample site) and by stratum:

1. vegetation (Holstein heliophyte covertype plus additional species list);
2. grazing occurrence;
3. intrazone land use;
4. adjacent land use;
5. stream channelization analysis;
6. artificial vs natural stream comparisons.

Remote Sensing Data Base

The total data base available in a stereoseries of high resolution natural color transparency film is very large. The present study utilized only a portion of those data, owing to time and funding constraints. Other parameters amenable to study with the data base include, for example:

1. percent crown closure;
2. dead tree/snag index;
3. areal extent of riparian vegetation;
4. edge length of riparian system;
5. riparian system shape index;
6. vegetation species interspersion;
7. configuration of occult riparian zones.

Discussion

Riparian systems are at the same time so important as a natural resource and so limited in individual size as to both merit and require higher resolution inventory procedures than those deployed for the larger, zonal uplands. The inherent structural diversity of most riparian systems is very large, and is compressed into such a small space that more zonal inventory methods cannot elucidate it with any success. By combining the attributes of stratified randomized sample site selection, nonrandom special site selection, remote sensing, and structural/floristic ground surveys, many useful inventory parameters can be quantified. The present methodology permits the establishment of structural, floristic, condition, and use baselines and facilitates their monitoring over time, since each transect point is fixed and can be located on aerial photos and replicated at a later date. Similarly, broader trends in structure and condition can be monitored over time where management strategies are being applied to large zonal upland areas through which the systems pass. Reliability limits for the findings can be manipulated by sampling intensity, both through the numbers of sample sites and the total site-specific field effort (e.g. transects, transect point frequency) invested. Additional parameters can be added to enrich the total data base as required.

Final analysis of data for the California Riparian Study Program is still underway, with publication of findings in 1981 (Katibah and Warner in press). More complete discussion of the methodology will be presented there.

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SINOPSIS

A pesar de su distribución universal y de su gran valor económico y ecológico, los sistemas riparios han sido grandemento ignorados y mal administrados como una recurso global. Este trabajo informa sobre los problemas asociados con su inventario. Un metodo inventario de tierra y de sentido remoto se combinó, y de experiencia desarrollada aplicándose a los sistemas riparios del Valle Central de California se describen. Con las apropiadas modificaciones para acomodar locales y necesidades específicas de estudio, el método es acomodable a cualquier sistema ripario, árido o semiárido.

Una definición universal de "ripario" se presenta, y una descripción que incluye las siguientes terrestres, zonas substratas riparios de suelo húmedo: a) las orillas de corrientes y ríos perenne y intermitentes; b) planos de aniegue y terraces de reboso; c) riachuelos, tierra suelto y praderas húmedos; d) arroyos del desierto, playas y "wadis"; e) oases; f) piscinas vernales; g) orillas de lagos, ojos de agua, pántanos y depósitos; h) tundra húmeda; y i) sanjas sin forro y vias de desague. Ambas la estructura y la florística de los sistemas riparios son amoldados por las apliamente regionales y temporales dimensiones de clima, geomorfología, topografía y biogeografía.

Los sistemas riparios varian en tamaño de grandes planos de anegación a pequeños riachuelos. Los inventarios zonales de tierra han tendido a ignorarlos, o a subestimar sus importancia. Las figuras de satélites y las fotos de los U-2 de 1:80,000-1:35,000 no tienan la resolución necesaria. Transparencias de color natural se han probado lo más útiles. Debido a complexidad estructural y a la necesidad de intrasistema detalle, estudios de campana in la misma localidad son indispensable.

La destruccion de los sistemas riparios es global y acelerando. La pérdida de vegetación confunde su estudio, ya que las dimensiones de las zonas no se pueden identificar con el uso sólo de información sobre la vegetación. Tales zonas "ocultas" deben ser deliniadas con fines de administración. La manipulación de fuentes de agua puede tener un efecto profundo en las sistemas riparios, y tales actividades deben ser incluídas dentro los límites de inventario cuando sea posible.

El area de estudio fue el Valle Central de California, un gran abrevadero rodeado de cadenas de montañas, y con un area más grande que 131,000 km^2. El clima va desde el desierto en el sur hasta el semiárido en el norte. Las presas y las desviaciones de agua han afectado grandemente la manera de correr del agua, y agricultura ha desplazado más de 200,000 hectares de selva riparias. La bombeacion del agua de la tierra ha disminuido las tablas de agua reduciendo zonas riparias a desiertos

Las necesidades principales del inventario incluyen: a) extensión areal y linear; b) situación; c) extructura y florísticas de la vegetación; d) condición de la vegetación y las tendencias de ésta; e) tipos y grados de use de intrasistemas; f) usos de tierrar adyacent; g) riqueza de especies y la distribución de pájaros que dependen de las zonas riparias; h) efectos de la canalización y otros tipos de manipulaciones hidrológicas; i) otros amenazas dicernibles a los recursos; j) potenciales para restaurar ambos la vegetación y las zonas ocultas; y otros.

Un juego de categorias de demarcación (mapping), en vez de un sistema de clasificación fue usado aunque el último tiene ventajas. Las categorias usadas están enumeradas. Un proceso de selección impesado y estratificado fue usado. Un subjuego de 20 sitios inimpesado fue también seleccionado con la base de sus particularidades, por estar relativamente intactos, y por su interés ecológico. Estudios de sentido remoto fueron hechos de 168 sitios de prueba; estudios con base terrestre fueron hechos en 55 sitios de prueba de los cuales 20 fueron inimpesado. Un equipo de campaña de dos hombres fue usada para las estudias de base terrestre, a un día por cada sitio. Esto resultó inadecuada para los sistemas largos o complejos; dos días por sitio o un equipo de 3-4 se recomienda.

Los parametros estructura, florística, condicion y uso fueron contados o estimados. Se indican en las figuras 1 y 2 que también ilustran la información del campaña en su formato. Transectos fueron cruzados en sistemas en puntos seleccionados, y la altura de cubretierra, cubre-arbustos, debajo de pabellón y pabellón fueron medidos. El diámetro de la vegetación de madera mas grande que 2 cm fue medida también. Los pájaros dependientes de las zonas riparias fueron localizados y transectos trepados en los sitios para caracterizar los sitios donde habitan. Ya que la densidad de especies de pájaros es difícil y lleva mucho tiempa para medir, medidas de la riqueza de especies y la relativa abundancia se recomiendan para inventarios extensos.

Estadísticas simples y descriptivas están siendo analizado. Estas son buenas para caracterizar sistemas individuales. Estadísticas analíticas que son buenas para comparar sistemas siendo evaluadas ahora se discuten. Se recomiendan mucho las estadísticas no-paramétricas, por su simplicidad y por no conocidas intratractas y intertractas variaciones. Parametros adicionales pueden ser añadidos a la metodología a la medida que se necesiten y como las recursos dicten. Varios son mencionados.

Procedimientos de sentido remoto se utilizaron son descritos. Una cámara Hasselblad con un lente de 100 mm usando Ektachrome MS, de tipo 2448 fue usado. Esto demonstró ser más eficiente que el film de color falso "infrared". La escala fue de 1:6,000, con 60% covertura para un alcance de estereo. Procedimientos de la interpretación de las fotos y del analisis son descritos.

La metodología permite el establecimento de bases de líneade la estructura, condición, florística y uso. También permite el estudio de cambios que resultan de programas de manejo.

Algunas Observaciones sobre las Poblaciones de las Mamíferos Pequeñes de la Sierra de la Laguna, Baja California Sur.[1]

Bronisław W. Wołoszyn[2]

Danuta Wołoszyn

Resumen. Se presentan resultados preliminares de estudios sobre los mamíferos pequeños de la Sierra de la Laguna, B.C.S., Se da una evaluación de la densidad y la biomasa de los roedores en la zona arbolada de la Sierra en base a los resultados por el método de "Standard-Minimum". Se presenta una evaluación de la dinámica de la población de los roedores en varias épocas del año, encontrando que en Octubre la densidad de los roedores es 2.21 y la biomasa es 2.27 mas grande que en Junio. Se observa una reciente migración de ratones del género Perognathus a la zona arbolada de la Sierra.

INTRODUCCION

El Estado de Baja California Sur cuenta únicamente con una cordillera importante que se localiza en el extremo meridional de la Península. La cordillera en su parte mas alta recibe el nombre de "Sierra de la Laguna". El resto de la parte sur de la Península carece de bosques y se caracteriza por una vegatación árida y semiárida.

El Centro de Investigaciones Biológicas de Baja Calironia, A.C., (CIB) realiza en la zona arbolada de la Sierra un amplio estudio sobre el ecosistema del bosque. Los autores que participan en este proyecto investigan a los mamíferos pequeños de la Sierra y el papel de éstos en el flujo de energía dentro del ecosistema.

MATERIALES Y METODOS

Area de Investigación.

El área de investigación está limitada al Norte del Arroyo de las Sabanas, al Noreste de la zona costera desde Las Palmas hasta Eureka, al Sureste a lo largo del Arroyo de Santiago, al Sur a lo largo del Cañón de Agua Caliente. El límite al Oeste aún no se ha fijado, sin embargo se limitará por la parte del Pacífico de la Montaña (Fig. 1,2,3).

Figura 1. Parte del sur de la Península de Baja California. El área investigada se marca con rayas.

Fig. 2. Fotografía de la Sierra de la Laguna

[1] Trabajo presentado en el Evento Internacional "Inventarios de Recursos de Zonas Aridas", La Paz, B.C.S., México, Nov. 30 - Dic. 6, 1980.

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Figura 3. Vista general al Cañón de la Zorra. Las partes más altas de la montaña están cubiertas por bosque-encino.

Método de Muestreo

Para obtener un conocimiento sistemático, biogeográfico y ecológico sobre la fauna de los mamíferos pequeños de la Sierra de la Laguna se toman muestras de todas las zonas bióticas de la sierra, que comprende: la selva baja, el bosque de galería, el bosque de transición y el bosque de pino-encino, tratando de abarcar todos las especies que viven en la montaña.

Los métodos aplicados durante nuestra investigación son cualitativos y cuantitativos como: el "Standard-Minimum", líneas de las trampas, redes para atrapar a los murciélagos, observaciones de los mamíferos en el campo, búsqueda de restos de los mismos, e investigación de sus huellas.

Entre los cuantitativos un método muy conocido y recomendado por "International Biological Program" (Ryszkowski, 1969) es el "Standard-Minimum". Este método fué desarrollado por ecólogos polacos (Grodzinski, Pucek, Ryszkowski, 1966) y posteriormente aplicado en varias partes de Europa y América del Norte (Petrusewicz 1967, 1969/70). En su forma original el método se aplica como sigue:

En un área de 5.76 hectáreas se instala una red de trampas ratoneras que consta de 16 x 16 filas. Cada estación de colecta donde se cruzan las filas se encuentran separadas por 15 m de distancia. En cada una de las 256 estaciones de colecta se colocan cebos durante los 5 primeros días al inicio del experimento, posteriormente se instalan dos trampas ratoneras por estación y se continúa el trampeo los cinco días siguientes.

En éste método la captura y separación de individuos afecta seriamente la población y puesto que la captura es proporcional a la población existente, es fácil evaluar la población inicial usando el método de regresión (Hayne, 1949) o métodos desarrollados por Zippin (1958).

Aunque hay también varios métodos cuantitativos, como por ejemplo el método "Captura-recaptura", (Smith et al, 1969, Stickel, 1954), nosotros usamos el método "Standard-Minimum" por las siguientes razones:

1. Económicos (Tabla 1)

Tabla 1. Diferencia económica entre los métodos: "Captura-recaptura" y "Standard-Minimum"

	Captura-recaptura	Standard-Minimum
1. Cantidad de las trampas	200	300[1]
2. Volumen de una trampa	8x8x26	3x9x17 cm
3. Volumen total de la unidad	0.25 m^3	0.14 m^3
4. Peso de una trampa	0.39 kg	0.15 kg
5. Peso total de la unidad	78.00 kg	45.00 kg
6. Precio de una trampa	150.00 M.N.	15.00 M.N.
7. Precio de la unidad	30,000.00 M.N.	4,500.00 MN

2. Técnicos: el transporte de la unidad de las trampas a la montaña y la instalación de las mismas requiere, en el método "Captura-recaptura" de 2 o 3 veces mas trabajo o sea de 1 a 2 personas más para manejar los ejemplares vivos capturados.

3. Biológicos: el método "Standard-Minimum" proporciona cierta cantidad de ejemplares durante un tiempo relativamente corto lo que tiene una gran importancia para estudiar la sistemática y biogeográfica de los mamíferos en las zonas muy poco conocidas como es la Sierra de la Laguna.

RESULTADOS

1. Desde el mes de Mayo de 1980 realizamos en la Sierra de la Laguna 180 "Dias-prueba" abarcando 60 localidades y puntos de colecta.

Durante este período investigamos mas de mil ejemplares, que pertenecen a los grupos de mamíferos que viven en la montaña, como: Insectivora, Chiroptera, Rodentia, Logomorpha, Carnivora y Artiodactyla. Anotamos 35 especies de mamíferos de los cuales no menos de 4 son nuevos para toda Baja California y algunos más son nuevos para la Sierra de la Laguna.[2]

1. Debido a que el área de investigación carece de terrenos planos se instalaron un menor número de trampas en un área más limitada tanto en el SM-1 y SM-2.

2 Los resultados que corresponden a la sistemática y biogeografía de los mamíferos serán publicados por separado.

2. Hemos realizado dos pruebas "Standard-Minimum". Las dos se tomaron del bosque pino-encino, cerca del campamento "Palo Extraño a una altura 1600 m sobre el nivel del mar (fig. 4). La tabla 2 lleva datos técnicos sobre las dos pruebas. Los resultados del trampeo se muestran en las tablas 3 y 4.

Tabla 2. Comparación de las dos pruebas "Standard-Minimum" tomadas en la zona arbolada de la Sierra de la Laguna.

	SM-1	SM-2
Fecha de investigación	6/14 de Junio/80	17-27 de Oct/80
Area Investigada	1.8[2]	3.0[2]
Cantidad de las estaciones de colecta	116	144
Cantidad de las trampas (tipo "snap-traps")	232	288

Figura 4. Bosque pino encino de la Sierra de la Laguna. En el fondo (centro) se ve el area donde se aplicaron las dos pruebas "Standard-Minimum".

Tabla 3. Resultados del trampeo de las dos pruebas "Standard-Minimum"

Dias de empleo	SM-1		SM-2	
	N	%	N	%
1	39	75.0	58	35.6
2	4	7.7	27	16.6
3	7	13.5	30	18.4
4	2	3.8	23	14.1
5	-	-	16	9.8
6	-	-	9	5.5
Total	52	100.0	163	100.0

[2]Vease la nota al pie de la tabla 1

Tabla 4. Distribución de los roedores en las pruebas SM-1 y SM-2.

Genero	SM-1		SM-2	
	N	%	N	%
Neotoma	2	3.8	9	5.5
Peromyscus	50	96.2	125	76.7
Perognathus	-	-	29	17.8
Total	52	100.0	163	100.0

3. La densidad de la población en la prueba SM-2 de Octubre resulta 2.21 mas que en prueba SM-1 de Junio (Fig. 5, Tabla 5). Este fenómeno se puede explicar de la siguiente manera: la primera prueba fué tomada en un período muy poco favorable para los roedores ya que la escasez de agua y alimentos disponibles disminuyen mucho la población, siendo un equivalente biológico al fin de invierno en las zonas de mayor altitud geográfica (Stoddart, 1979). Al fin de época de lluvias la población alcanza su máximo (Stoddart, op. cit., Mares, 1973, Wojciechowska, 1969).

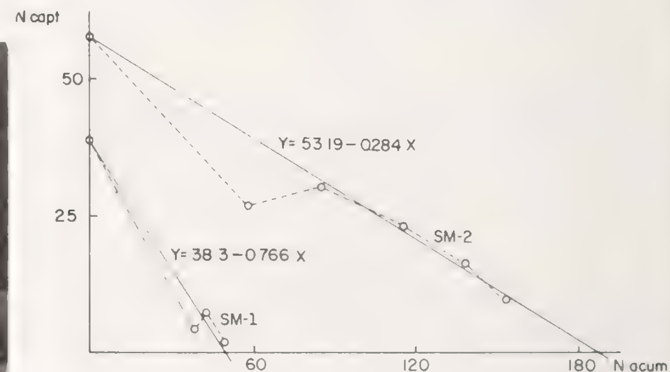

Figura 5. Cálculo de la densidad de los roedores aplicando el método de regresión a las pruebas SM-1 y SM-2. Los puntos blancos indican las muestras diarias.

Tabla 5. La dinámica de la densidad y la biomasa de los roedores (Neotoma, Peromyscus, Perognathus) en el bosque pino-encino de la Sierra de la Laguna.

	SM-1 Junio	SM-2 Octubre
Ejemplares capturados	52	163
Densidad calculada (Ind/Ha)	28	62
Biomasa calculada (gm/Ha)	660	1497
Standing crop (gm/m2)	0.066	0.15

4. La biomasa de los ejemplares capturados resulta 1225 y 4041 gramos por el área de SM-1 y SM-2 respectivamente. La cuantificación de la biomasa representada por ejemplares jóvenes no aptos para atraparse se llevó a cabo de la siguiente manera:

Por la prueba de SM-1 se mustrearon 50 ejemplares de Peromyscus y solamente se encontró una hembra embarazada que constituyó el 2% de la población. De los ejemplares atrapados no se encontraron ejemplares de menos de 15 gramos lo que sugiere que la población en esta época del año (junio) está constituída por ejemplares adultos y subadultos. Durante el trampeo se atraparon 2 ratas del género Neotoma las cuales no mostraron signos de estar en el período de reproducción.

Al aplicar la prueba SM-2 en 125 ejemplares de Peromyscus se encontraron 10 hembras en estado de lactancia, lo que representa por esta prueba el 8% de la población. Se puede suponer que cada hembra alimentaba a dos hasta 4 crías (en promedio 3 crías) lo que representa un promedio de 30 ejmplares que permanecieron en sus madrigueras. Según los resultados del muestreo, los ejemplares que pesan de 8-10 gramos son trampeables, lo que sugiere que los ejemplares más jóvenes tienen un peso aproximado de 5 gramos, por lo tanto la biomasa total de ejemplares no activos, no debe exceder de 150 gramos.

Con respecto al género Neotoma se colectaron dos hembras en estado de lactancia y de una manera arbitraria suponemos que 5 crías permanecen en las madrigueras con un peso de 50 g cada uno lo que representa una biomasa total de 250 gramos.

Con respecto al género Perognathus se encontró solamente una hembra en estado de lactancia. Dentro de ejemplares más jóvenes que se colectaron su peso oscilaba entre 11 - 13 gramos lo que sugiere que en la madriguera se quedaron 3 crías con un peso aproximado de 8 a 10 gramos que constituye una biomasa total estimada en 30 gramos.

De acuerdo a lo anterior estimamos que el peso total de ejemplares jóvenes que permanecen en las madrigueras de los tres géneros, no debe exceder de 450 gramos por área de investigación.

Pues, la biomasa total calculada de la prueba SM-2 resulta 4491 gramos por área de investigación.

Se observa que la biomasa de los roedores aumenta de Junio a Octubre 2.27 veces, ocupando por su volumen un lugar medio entre las zonas frías o templadas de América del Norte, Europa y zonas calientes de América y Africa (Tabla 6).

Tabla 6. Comparación de la densidad y biomasa de los roedores en zonas de diferente clima (según Golley, 1960; Odut et al, 1962, Stoddart, 1979, adaptado).

Descripción	Densidad (Ind/ha)	Biomasa (g/ha)	Standing crop (g/m2)
Alaska (bosque Picea)	4.6	253.14	0.025
Suecia (bosque Picea)	13.25	344.88	0.035
Polonia (bosque Querceto-carpinetum)	8	183.23	0.018
Georgia (USA)	25	300	0.003
Baja California. Sierra de la Laguna, bosque pino-encino (datos propios)	min. 28 max. 62	660 1497	0.066 0.15
Michigan (USA) datos para Microtus pensylvanicus)	50	1450	0.145
Panamá (bosque tropical húmedo)	11.3	6304	0.63
Lago Kivu-Zaire	370	14000	1.4

5. La figura 6 muestra el peso medio de los ratones Peromyscus a diferentes dias de trampeo. Durante la primera prueba (SM-1) el peso medio descendió progresivamente con respecto al tiempo. Este descenso fué moderado ya que los ejemplares jóvenes fueron escasos y el tiempo de colecta relativamente corto, lo cual no permitió la migración de ejemplares de terrenos vecinos.

Durante la segunda prueba (SM-2) aunque el peso medio inicial fué casi igual (19.4 y 19.3 g respectivamente) este desciende bruscamente durante los 4 dias siguientes. Al quinto dia se capturaron ejemplares de migración ya que el percentaje de ejemplares atrapados en el perímetro del área, fué del 100% de la muestra diaria. De estos ejemplares el 50% fueron adultos en un peso de 20 o mas gramos. Al día sigiente la migración continúa aunque ésta disminuye un poco (4 ejemplares con un peso medio de 19.5 gr) pero se atraparon en la zona centro 3 ratones muy jóvenes con un peso medio de 10.0 gr.

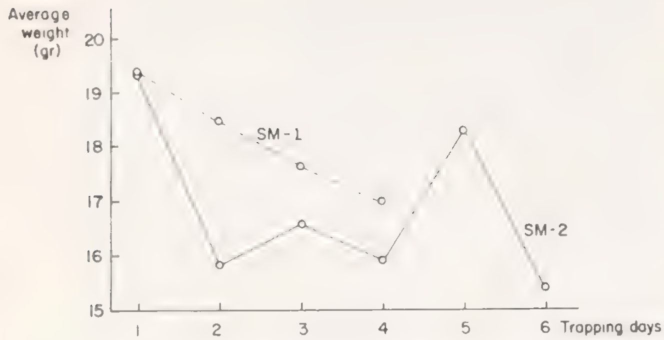

Figura 6. Peso medio de los ratones Peromyscus a diferentes días de trampeo por las pruebas SM-1 y SM-2.

6. Un fenómeno notable es la migración reciente de roedores del género Perognathus hasta la zona templada de la Sierra (tabla 4). Este fenómeno se puede explicar de 2 maneras. Puede ser cierta población de Perognathus que ocupa algunos lugares semiáridos en zonas más elevadas de la montaña realiza una migración temporal causada por la abundancia de alimentos disponibles en la zona arbolada, o puede indicar ciertos cambios dentro del ecosistema. Aún faltan datos que nos permitan explicar suficientemente este fenómeno.

7. Se ha observado que la biomasa y relativa abundancia no se distribuyen igualmente (Stoddart, 1979), lo cual es congruente en nuestras investigaciones sobre la distribución de las ratas del género Neotoma (tabla 7) y los ratones del género Peromyscus, donde la densidad de Peromyscus es de 25-14 veces más abundante que la de Neotoma y la biomasa apenas 5.9-3.7 mas grande con respecto a la densidad y biomasa de Neotoma en las dos pruebas respectivamente.

Tabla 7. El papel de los roedores del género Neotoma en la densidad y biomasa de los roedores.

SM-1		SM-2	
% de la población	% de la biomasa[1]	% de la población	% de la biomasa
3.8	14.4	5.5	22.8

[1]Calculada de la biomasa efectiva.

8. Es notable también que entre el género Perognathus se encuentran dos veces más hembras que machos, mientras tanto en el género Peromyscus la población desde este punto de vista, es mas equilibrada (tabla 8ab). La baja cantidad de machos Perognathus puede significar una gran eficiencia de fecundación o una gran dispersión de los machos despues del período de reproducción.

Tabla 8 a,b. Cantidad de individuos capturados en pruebas SM-1 (a) y SM-2 (b) de los generos Peromyscus y Perognathus según peso y sexo.

Tabla 8 a (M-machos, F-hembras)

Peso (en gr)	Sexo	SM-1 Peromyscus N	%
15-20	M	18	36.0
	F	21	42.0
20-25	M	7	14.0
	F	4	8.0
Total		50	100.0

Tabla 8 b (M-machos, F-Hembras)

Peso (en gr)	Sexo	SM-2 Peromyscus N	%	Perognathus N	%
8-10	M	3	2.4	-	-
	F	5	4.0	-	-
10-15	M	20	16.0	2	6.9
	F	18	14.4	6	20.8
15-20	M	20	16.0	3	10.3
	F	20	16.0	6	20.8
20-25	M	15	12.0	3	10.3
	F	18	14.4	7	24.1
25-30	M	-	-	1	3.4
	F	6	4.8	1	3.4

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SOME OBSERVATIONS ON POPULATIONS OF SMALL MAMMALS OF THE SIERRA DE LA LAGUNA, BAJA CALIFORNIA

Bronisław W. Wołoszyn
Danuta Wołoszyn

The state of Baja California Sur has only one important mountain range which is located in the extreme south of the peninsula. The highest part of this mountain range is called "Sierra de la Laguna". The Centro de Investigaciones Biológicas de Baja California, A.C. (C.I.B), is carrying out extensive studies of the ecosystem of forest areas of the Sierra. The authors participate in this project, investigating the small mammals of the Sierra and their roles in the energy flow inside this ecosystem. The area of our investigation is limited to the northern part of the Arroyo de las Sabanas, to the northeast of the coastal zone from Las Palmas to Eureka, to the southeast for the length of the Santiago River, to the south for the length of the Agua Caliente Canyon. The western limit ends on the pacific side of the mountain.

The methods applied during our investigation are qualitative and quantitative such as: "Standard-Minimum", trap lines, mist nets for trapping bats, observations of the wild mammals, search for the remains of these and investigation of their tracks.

Samples are regularly taken from all the biotic zones of the Sierra which includes the lower selva, the Bosque de Galeria, the transition forest and the pine-oak forest in an attempt to investigate all the mammal species that live in the mountain.

Among the quantitative methods is one method very well known and recommended by the International Biological Program which is the "Standard-Minimum" method (Ryszkowski, 1969). This method was developed by polish ecologists (Grodziński, Pucek, Ryszkowski, 9166) and later applied in various parts of Europe and North America (Petrusewicz, 1967, 1969/70). Although there are various quantitative methods, we use the "Standard-Minimum" method for economical, technical and biological reasons (Table 1).

Since May of 1980 we have spent 180 "test days" in the Sierra de la Laguna working in 60 different localities and collection points. During this time we have investigated more than 1000 specimens which belong to Insectivora, Chiroptera, Rodentia, Logomorpha, Carnivora and Artiodactyla groups. We noted 35 species of mammals. The results related to systematic and biogeography will be published apart.

We have taken 2 Standard-Minimum tests. The 2 tests were taken in the pine-oak forest near the "Palo Extraño" camp at an altitude of 1,600 meters above sea level (Fig. 3 & 4). Table 2 presents technical data about the 2 tests. The results of the entrapment are shown in tables 3 & 4.

The population density in the Standard-Minimum test #2 in October was 2.21 times larger than that in the Standard-Minimum test #1 of June (Fig. 5, Table 5). This difference can be explained in the following manner: the first test was taken during a time that was unfavorable for the rodents, since the scarcity of water and available food lowered the population. At the end of the rainy season, the population reaches its maximum (Stoddart, op. cit., Mares, 1973).

The biomass of the captured specimens is 1,225 grams in the Standard-Minimum test area #1. In the Standard-Minimum test area #2 the biomass of captured specimens is 4,041 grams for the area. In this test we encountered many young specimens that cannot be captured. We calculate that the total weight of these young specimens that belong to Neotoma, Peromyscus and Perognathus should not exceed 450 grams. Therefore, the total biomass calculated in the Standard-Minimum test #2 is 4,491 grams for this investigation area. It is observed that the biomass of the rodents increases from June to October 2.27 times (Table 5). An interesting observation is the recent migration of the rodents of the genus Perognathus to the temperate zone of the Sierra (Table 4). This observation can be explained as a temporary migration to the forest during a time when there is an increase in the abundance of available food or it could indicate changes within the ecosystem.

Moderator's Summary of Efficient Resources Measuring Techniques for the Arid Lands

David R. Bower[1]

Emphasis should be given to the cost effectiveness and precision of sampling schemes for arid land resources. The cost effectiveness of five sampling schemes has been compared for estimating various parameters (height, diameter, volume, etc.) of Datilillo and Cardon (Quintana, et al.). Results are described in their paper. Standard point sampling theory can be used to estimate shrub density, crown density, bunchgrass density and tree basal-area (Beers). The sparseness and low productivity of desert vegetation commonly requires different sampling methodologies. Allometric approaches have been used to relate dimensions of remaining vegetation components to harvested portions (West). A rapid, efficient survey method has been developed for assessing the importance of a plant species within the community, and is relatively unaffected by year-to-year fluctuations in cover (Pase). Different plot shapes may be helpful in arid land sampling. Diagonal plots were found to be more accurate than circular plots and to require less time for layout than rectangular plots (Zeide). Special sampling frames may be helpful. A 2 x 5 foot wire frame, subdivided into 10 one square foot segments, has been found effective in measuring the square feet of ground surface stocked with plants on salt desert shrub vegetation areas in central Utah (Frischknecht).

Standard regression procedures are also useful. Biomass regressions were developed to estimate the dry weight of Agave and Hechtia, in the arid region of Tehuacan, Mexico, as a linear function of volume. Volume was calculated from height and crown width (Gonzales, et al.). The trade-off between volume estimation via dendrometer versus volume estimation via equations is discussed (Bower). A key point, is that the dendrometer method requires bark thickness estimates to get inside bark volumes. New procedures are now available for making the bark thickness estimate (Deusen, et al.). New equations are also presented for estimating volume to any merchantable top diameter, and for predicting merchantable height to any top diameter limit (Matney and Sullivan). A visual tree diagramming and classification system has been used with regression equations to help estimate pinyon-juniper resource in Nevada (Rhea and McGlothlin).

Wildlife is an important arid land resource. A removal method has been developed which is an intensive short duration technique involving "instantaneous" capture of animals in discrete areas. The procedure is highly cost effective (Bury). Fecal analyses for arid land food habit surveys have advantages of low cost, budget flexibility, and minimal disturbance of wild animals (Cooperider, et al.).

Aquatic and riparian habitat are the most important and some of the most limited of wildlife habitat in arid regions. An integrated system for evaluating aquatic and riparian habitats can be developed and can be used to predict impacts of management activities (Armantrout).

Arid areas in Kenya are being reclaimed through irrigation. Degree of salinity is an important factor in determining suitability for surface irrigation and a new procedure is presented for comparing methods of measuring salinity (Ngaruiya).

Mesquite gum is very important since its chemical composition resembles that of arabic gum which is used in industry. Machete and diagonal cuts can be effectively used to obtain gum from Prosopis laevigata (Espejel).

A combination of 35 mm and 70 mm aerial photography with an extensive ground survey is used to inventory caribbean pine plantations in Venezuela (Rhody).

Land Sat imagery, color aerial photography and ground data collection are combined in the inventory of soil, vegetation, and water resources for the Republic of Mali in West Africa (Treadwell and Buursink).

The details of the inventory procedures described in this measurement techniques session should prove of high value to managers of the arid land resources.

[1]Weyerhauser Company, Southern Forestry Research Center, Hot Springs, Arkansas.

Sistemas de Procesamiento de Datos para Inventarios Forestales en México[1]

Sergio M. Varela Hernández[2]

Resumen.– Se presentan algunos de los sistemas de cómputo más usuales que se aplican en México, en la cuantificación de los recursos forestales. Se dá la siguiente información: título, autor(es), descripción, objetivos, datos de entrada, datos de salida, modelo de computador, aplicaciones, información complementaria y contactos para información técnica.

Durante el último cuarto de siglo, las técnicas de cuantificación de los recursos forestales en México, han registrado un significativo avance en lo que se refiere a mediciones de campo, técnicas de muestreo, elaboración de cartografía, y en el análisis y presentación de resultados.

En cuanto a los sistemas de procesamiento de datos, el avance ha sido de igual o mayor magnitud, toda vez que el área de la cibernética es de las ciencias más desarrolladas en el mundo.

La adopción generalizada del cómputo electrónico en inventarios forestales, se dá a principios de la década de los sesentas, y acontece bajo las circunstancias de que el cálculo efectuado por una máquina computadora electrónica, es semejante mecánicamente, al realizado a mano con calculadoras de mesa, por un calculista adiestrado. Las instrucciones que se dan a la computadora en forma codificada, son una réplica del proceso manual, solamente que con algunas modificaciones según el tipo de computador.

Durante el proceso de aceptación del cómputo electrónico, no fueron pocas las objeciones encontradas al nuevo sistema, dándose paulatinamente su adopción definitiva y necesaria.

Hoy en día, no podemos concebir empresa alguna, que maneje una cifra medianamente gruesa de datos, que no disponga por lo menos de una minicomputadora.

En el desarrollo de este trabajo se expondrán algunos de los sistemas de procesamiento que se emplean en inventarios forestales en general.

SISTEMAS DE COMPUTO EMPLEADOS EN EL INVENTARIO FORESTAL CONVENCIONAL

Como es de todos conocido, el inventario forestal del país se inició hace 19 años, con el propósito de estudiar las características cualitativas y cuantitativas de la vegetación arbolada, así como de elaborar la carta forestal del país.

De acuerdo con estos objetivos y para obtener la información pormenorizada de volúmenes, incrementos, frecuencias, etc., se diseñaron cuatro sistemas básicos de cómputo, integrados por un número que rebasa los 40 programas en total:

- Existencias volumétricas
- Incrementos en volumen
- Sistema de dendrómetro para obtener tablas de volúmenes
- Sistema de datos ecológico—silvícolas

En virtud de que los sistemas de existencias volumetricas y de incrementos están enfocados a la obtención de volúmenes maderables en bosques y selvas, se presentan únicamente a nivel de mención, sus diagramas se indican en las figuras 1 y 2. Con motivo de esta reunión me referiré a los sistemas de dendrómetro y ecológico—silvícolas, en virtud de que estos son totalmente aplicables a los inventarios de zonas aridas, cuyos productos se han denominado genéricamente, no maderables.

Titulo del Sistema: Dendrómetro

Autor: Dirección General del Inventario Forestal.

Descripción: es un sistema en Batch integrado por nueve programas de cómputo electrónico, que permiten efectuar la verificación, la corrección de los datos, la obtención final de las tablas de volúmenes y la conservación del archivo (fig. 3).

Las fases más importantes del sistema son:

Cubicaciones individuales: el reporte de este programa hace posible efectuar una última revisión de las lecturas X, Y y Z, en función de las variables diámetro y longitud de cada una de las secciones.

Regresiones: para ajustar los resultados de las cubicaciones individuales, a fin de obtener valores medios, se prueban diferentes valores matemáticos, mediante el paquete S.A.S. (Statystical Analysis System), disponible en la Universidad Autónoma de Chapingo.

Tablas de volúmenes: obtenido el modelo matemático de regresión y las constantes respectivas para los grupos de especies que constituyen una tabla de cubicación, se procede a su impresión, fase con la que concluye el sistema.

Objetivos.

Mediante la aplicación de este sistema se obtienen los valores en volumen de árboles seccionados imaginariamente, sin necesidad de su derribo y troceo. El objetivo primordial es obtener tablas que presenten, para una o más especies, el contenido volumétrico medio de árboles o de trozas, comúnmente llamadas tablas de volúmenes.

La información por procesar es captada en tarjetas en las que se marcan con lápiz de ferrita las lecturas en X, Y y Z del dendrómetro sobre los árboles muestreados. El uso de las tarjetas obedece a la facilidad de la toma de datos, ya que el número de variables es reducido. La verificación de datos por medio de programas de chequeo es más eficiente. El porcentaje de errores es de 5 por ciento del cual es posible corregir el 80 por ciento. Los errores no corregibles son del orden del 1 por ciento y se pueden desechar sin afectar el resto de la información.

Datos de salida.

Listados con valores en metros cúbicos de fuste total y fuste limpio, cuyas entradas son dos columnas, una de diámetros a la altura del pecho, y la otra con alturas del arbolado (fig. 4).

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[1]Trabajo presentado en la Reunión de Inventarios y Recursos de Zonas Aridas. (La Paz, México, noviembre 30—diciembre 6, 1980).

[2]Sergio M. Varela Hernández, Ingeniero Agrónomo Especialista en Bosques, egresado de la Universidad Autónoma de Chapingo — Subdirector de Inventarios de la Dirección General del Inventario Forestal.

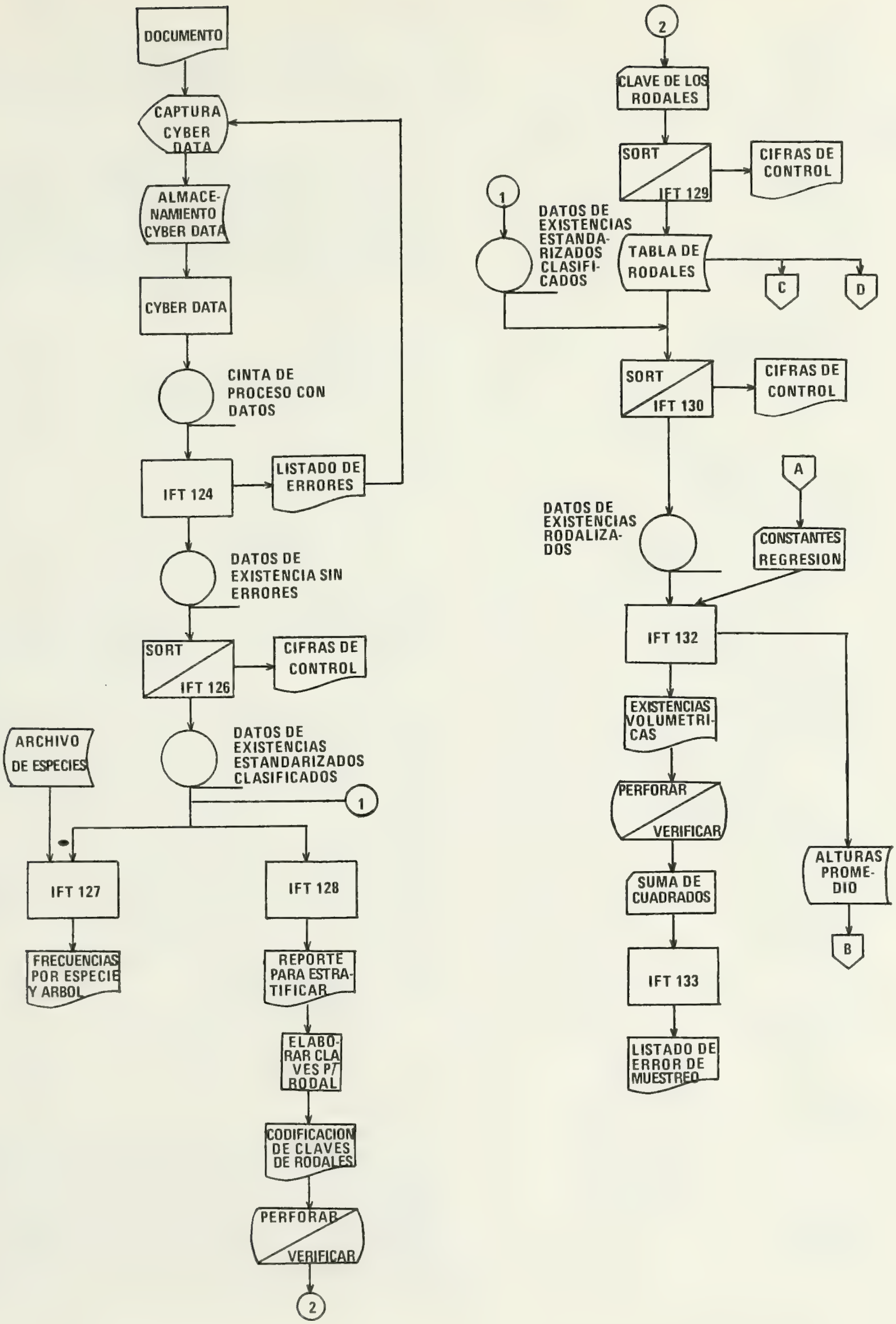

FIGURA 1.– Diagrama de sistema de existencias volumétricas.

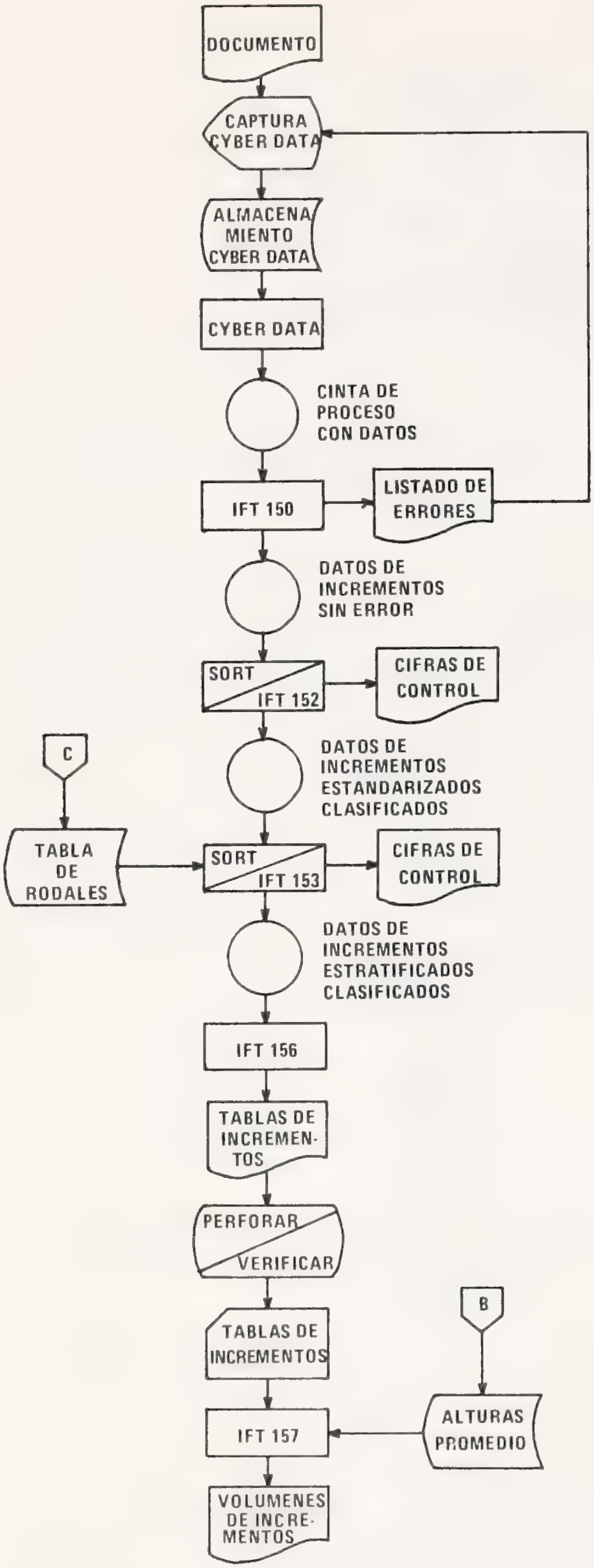

Figura 2.– Diagrama de sistema de incrementos volumétricos.

Computador.

Los programas están escritos en lenguaje Cóbol y se emplea una máquina Cyber 72/14 para su proceso. Anteriormente, el sistema se corría en la computadora IBM-370 de la Universidad Autónoma de Chapingo.

Aplicaciones.

El sistema se empleó en la Dirección General del Inventario Forestal desde 1963 en el estudio de los bosques del estado de Chihuahua, que fue la primera región inventariada. Actualmente, este conjunto de programas lo desarrolla la Dirección General de Información y Sistemas Forestales, para los diversos usuarios (Inventario Forestal, Instituto Nacional de Investigaciones Forestales, Unidades de Administración Forestal, instituciones educativas, etc.).

Contactos para información técnica.

Dirección General de Información y Sistemas Forestales
G. Pérez Valenzuela No. 106
México 21, D. F.
Tel.: 554-96-77

Departamento de Programación y Presupuesto
Av. Progreso No. 5
México 21, D. F.
Tel.: 554-81-55, ext. 16

Título del Sistema: Datos Ecológico-Silvícolas

Autor: Dirección General del Inventario Forestal.

Descripción: para su desarrollo se siguen programas muy semejantes a los del sistema anterior, particularmente en la fase de verificación, el computador y el lenguaje son los mismos (fig. 5).

Para correr el sistema, el computador registra los conceptos por estudiar, a partir de las perforaciones de las tarjetas. De esta forma se obtienen los datos, en porciento de los sitios que presentan una característica silvícola determinada.

Datos de entrada: daños al arbolado en pie, tipo de suelo, grado de erosión, exposición del sitio, pendiente, altitud y repoblado.

Datos de salida: son los mismos que de entrada, únicamente que se obtienen los listados señalando para cada concepto, su frecuencia y porcentaje.

Como se observa en la figura 6, se recomienda este sistema para ser aplicado en inventarios forestales de zonas áridas, en virtud de la valiosa información que se obtiene para los conceptos señalados.

Contactos para información técnica.

Dirección General del Inventario Forestal

Dirección General de Información y Sistemas Forestales

Sistemas de cómputo para Inventario Forestal Continuo

En la implantación de esta modalidad de inventario, el empleo del cómputo electrónico es indispensable. Tomando en cuenta las características de la metodología, que tiene como objetivo el estudio cualitativo y cuantitativo de las áreas arboladas, así como determinar la dinámica que en ellas tiene lugar, se requiere de un procesamiento de datos dinámico, versátil, confiable y económico. El procesamiento automatizado, por lo tanto, es una herramienta muy valiosa para realizar actividades como calcular, verificar, corregir y generar la información deseable. Es insustituible también en las fases de conservación para el posterior uso de archivos.

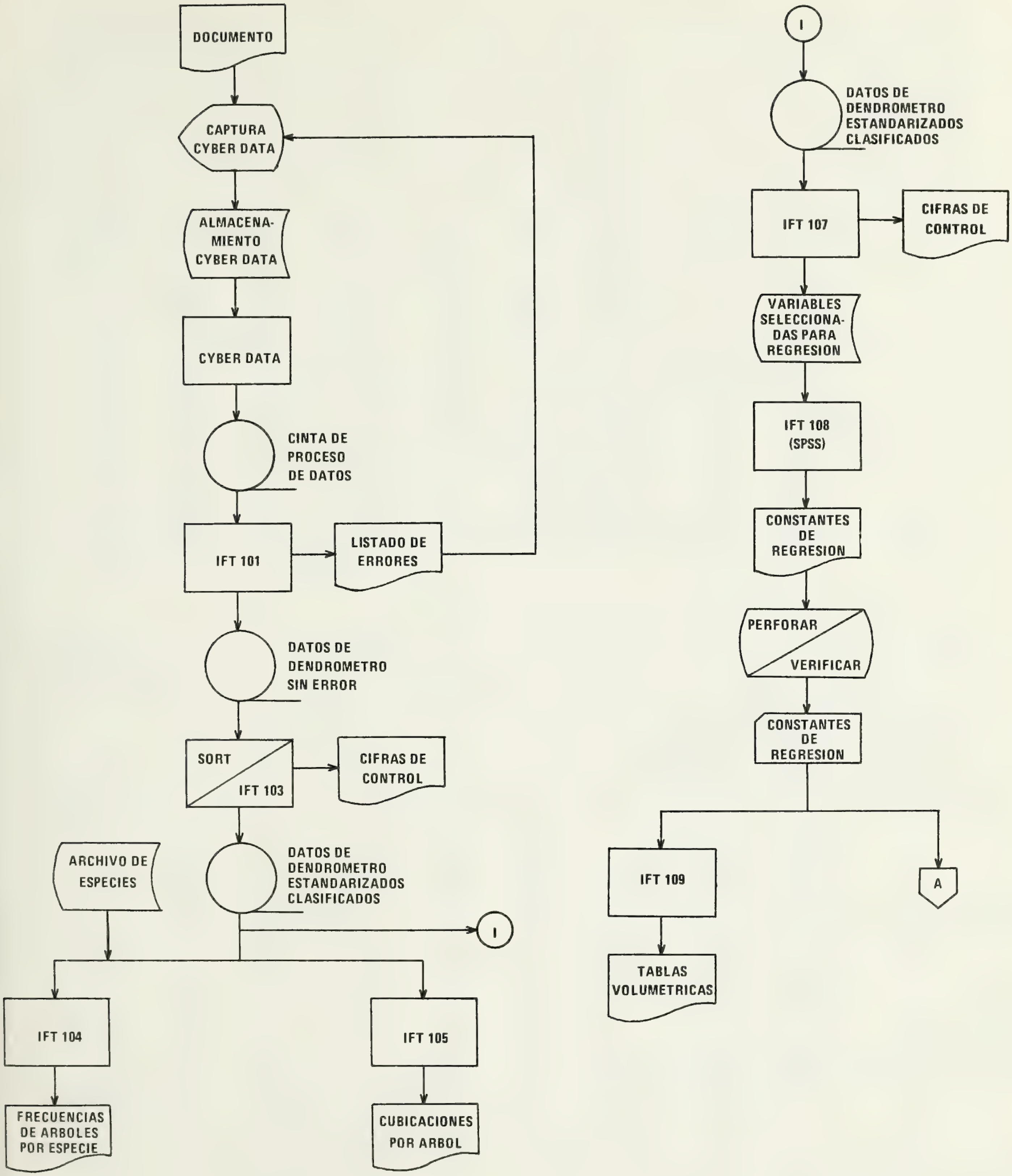

Figura 3.-- Diagrama del sistema de dendrómetro.

TABLA NUM. 3	REGION NORTE	Para cubicación de una especie del grupo botánico 17 (Ver apéndice III)							NUMERO DE OBSERVACIONES 20
CLASE DIAMETRICA (cm)	A L T U R A S								
	5 m	10 m	15 m	20 m	25 m	30 m	35 m	40 m	45 m
10	0.02022	0.04266	0.06603	0.09001	0.11446	0.13929	0.16445	0.18988	0.21556
15	0.04423	0.09330	0.14439	0.19684	0.25031	0.30462	0.35964	0.41526	0.47143
20	0.07705	0.16256	0.25157	0.34295	0.43612	0.53074	0.62659	0.72351	0.82136
25	0.11853	0.25006	0.38696	0.52754	0.67085	0.81641	0.96385	1.11293	1.26346
30	0.16651	0.35551	0.55018	0.75001	0.95376	1.16070	1.37032	1.58227	1.79628
35	0.22690	0.47869	0.74061	1.00987	1.28422	1.56286	1.84511	2.13050	2.41866
40	0.29360	0.61940	0.95657	1.30673	1.66173	2.02227	2.38749	2.75677	3.12963
45	0.36853	0.77743	1.20321	1.64023	2.08583	2.53839	2.99682	3.46035	3.92837
50	0.45163	0.95279	1.47452	2.01007	2.55615	3.11075	3.67256	4.24060	4.81415
55	0.54283	1.14520	1.77229	2.41599	3.07234	3.73895	4.41420	5.09696	5.78633
60	0.64209	1.35459	2.09634	2.85775	3.63411	4.42260	5.22132	6.02891	6.84433
65	0.74934	1.58087	2.44653	3.33512	4.24117	5.16137	6.09351	7.03601	7.98764
70	0.86456	1.82393	2.82269	3.84791	4.89326	5.95455	7.03042	8.11782	9.21577
75	0.98769	2.08370	3.22470	4.39593	5.59016	6.80306	8.03169	9.27397	10.52829
80	1.11870	2.36009	3.65243	4.97901	6.33165	7.70543	9.09703	10.50406	11.92478
85	1.25755	2.65302	4.10576	5.59700	7.11753	8.66182	10.22614	11.80784	13.40467
90	1.40421	2.96242	4.58459	6.24974	7.94760	9.67199	11.41676	13.18492	14.96820
95	1.55865	3.28824	5.08882	6.93711	8.82170	10.73574	12.67463	14.63503	16.61444
100	1.72084	3.63040	5.61834	7.65696	9.73566	11.85267	13.99350	16.15769	18.34328
105	1.89074	3.98835	6.17307	8.41517	10.70131	13.02517	15.37516	17.75326	20.15442
110	2.06835	4.36353	6.75293	9.20563	11.70651	14.24646	16.81938	19.42066	22.04757
115	2.25362	4.75440	7.35782	10.03022	12.75511	15.52259	18.32597	21.16048	24.02246
120	2.44653	5.16139	7.98767	10.88884	13.84699	16.85137	19.89474	22.97189	26.07888
125	2.64707	5.58446	8.64241	11.78138	14.98201	18.23266	21.52548	24.85486	28.21653
130	2.85521	6.02357	9.32196	12.70776	16.16006	19.66630	23.21604	26.80921	30.43521

TABLA NUM. 4	REGION NORTE	Para cubicación de los grupos botánicos 3, 4 y 5 (Ver apéndice III)							NUMERO DE OBSERVACIONES 682
CLASE DIAMETRICA (cm)	A L T U R A S								
	5 m	10 m	15 m	20 m	25 m	30 m	35 m	40 m	45 m
10	0.02397	0.04856	0.07340	0.09839	0.12349	0.14870	0.17398	0.19932	0.22473
15	0.05114	0.10361	0.15659	0.20991	0.26348	0.31724	0.37118	0.42526	0.47947
20	0.08755	0.17738	0.26808	0.35936	0.45106	0.54311	0.63545	0.72803	0.82083
25	0.13286	0.26916	0.40680	0.54530	0.68446	0.82414	0.96426	1.10474	1.24556
30	0.18680	0.37844	0.57195	0.76669	0.96234	1.15873	1.35573	1.55325	1.75124
35	0.24916	0.50479	0.76291	1.02267	1.28364	1.54560	1.80837	2.07184	2.33592
40	0.31979	0.64787	0.97916	1.31254	1.64749	1.98370	2.32096	2.65911	2.9980[illegible]
45	0.39853	0.80740	1.22026	1.63573	2.05316	2.47215	2.89244	3.31386	3.73626
50	0.48527	0.98311	1.48582	1.99171	2.49998	3.01016	3.52193	4.03506	4.54938
55	0.57988	1.17479	1.77551	2.38004	2.98741	3.59706	4.20860	4.82178	5.43639
60	0.68227	1.38224	2.08904	2.80031	3.51493	4.23223	4.95177	5.67322	6.39636
65	0.79236	1.60527	2.42612	3.25216	4.03209	4.91513	5.75077	6.58864	7.42846
70	0.91007	1.84373	2.78651	3.73526	4.68840	5.64527	6.60504	7.56737	8.53194
75	1.03531	2.09747	3.17000	4.24931	5.33371	6.42218	7.51403	8.60880	9.70611
80	1.16803	2.36634	3.57636	4.79403	6.01744	7.24543	8.47725	9.71236	10.95034
85	1.30816	2.65023	4.00540	5.36916	6.73934	8.11465	9.49425	10.87753	12.26403
90	1.45563	2.94900	4.45696	5.97446	7.49911	9.02947	10.56459	12.10382	13.64663
95	1.61040	3.26256	4.93085	6.60971	8.29646	9.98954	11.68789	13.39077	15.09762
100	1.77242	3.59079	5.42692	7.27468	9.13113	10.99454	12.86376	14.73796	16.61653
105	1.94163	3.93360	5.94503	7.96919	10.00237	12.04418	14.09185	16.14498	18.20290
110	2.11799	4.29090	6.48502	8.69304	10.91145	13.13817	15.37184	17.61145	19.85636
115	2.30146	4.66259	7.04673	9.44606	11.85663	14.27624	16.70339	19.13701	21.57631
120	2.49199	5.04659	7.63016	10.22807	12.83821	15.45814	18.08622	20.72132	23.36256
125	2.68955	5.44883	8.23505	11.03892	13.85599	16.68361	19.52004	22.36404	25.21467
130	2.89410	5.86322	8.86135	11.87845	14.90976	17.95243	21.00458	24.06467	27.13229

Figura 4.– Listados de cubicaciones del sistema de dendrómetro.

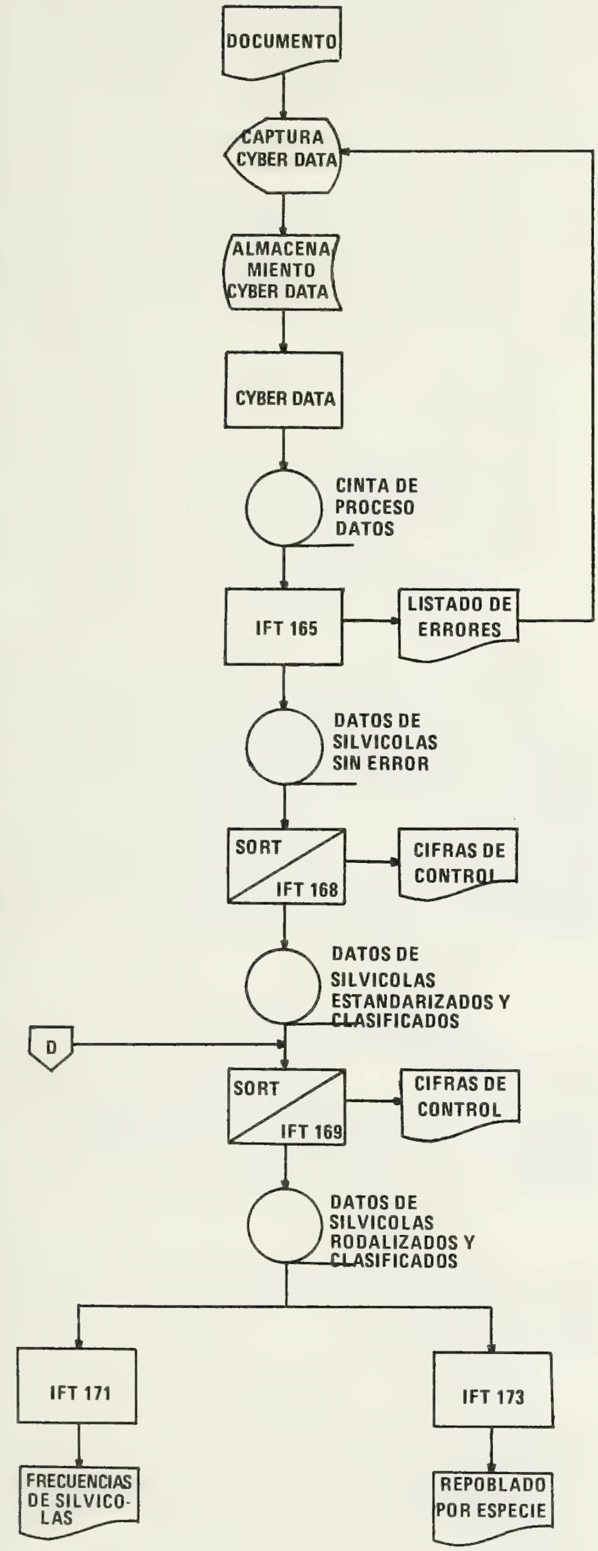

Figura 5.- Flujo del sistema de datos ecológico-silvícolas.

DATOS ECOLOGICOS-SILVICOLAS

	CONCEPTO	NUM. DE SITIOS	%
CAUSAS DE DAÑO AL ARB EN PIE	Sin datos	111	2.43
	Ausencia	3863	84.66
	Plagas	22	0.48
	Daño humano	116	2.54
	Viento	23	0.50
	Plantas parásitas	38	0.83
	Enfermedades	60	1.31
	Incendios	277	6.07
	Desconocidas	53	1.18
USO DEL SUELO	Sin datos	111	2.43
	Selva baja	68	1.49
	Selva alta	2933	64.28
	Acahual	173	3.79
	Sabana	1	0.02
	Selva mediana	1099	24.08
	Bosque mesófilo	1	0.02
	Corosal	0	0
	Desmonte	177	3.89
FISIOGRAFIA	Sin datos	109	2.39
	Valle	7	0.15
	Planicie	914	20.03
	Meseta	39	0.85
	Lomerío	1974	43.26
	Terraza	6	0.13
	Barranca	120	2.63
	Ladera	1384	30.33
	Bajo	10	0.22
PROFUND. DEL SUELO	Sin datos	115	2.52
	0-10 cm	219	4.80
	11-15 cm	100	2.19
	16-25 cm	0	0
	26 ó más cm	4129	90.49
	No identificado	0	0

	CONCEPTO	NUM. DE SITIOS	%
TEXTURA DEL SUELO	Sin datos	121	2.65
	Arcilla	266	5.83
	Limo	362	7.93
	Franco	450	9.86
	Migajón	467	10.23
	Arena	34	0.74
	No identificada	2 863	62.76
TIPO DE EROSION	Sin datos	121	2.65
	No perceptible	2477	54.28
	Laminar	1433	31.40
	Canalillo	433	9.49
	Cárcava	99	2.18
PORCENTAJE EN PENDIENTE	Sin datos	110	2.41
	0-10	1018	22.31
	11-15	1793	39.29
	16-25	967	21.19
	26-40	563	11.74
	41-100	133	2.91
	más de 100	6	0.15
EXPOSICION DEL SITIO	Sin datos	119	2.61
	Zenital	969	21.24
	Norte	774	16.96
	Sur	763	16.72
	Este	343	7.52
	Oeste	255	5.59
	Noreste	546	11.96
	Sureste	452	9.90
	Noroeste	165	3.62
	Suroeste	177	3.88
	TOTAL DE SITIOS	4563	100.00

Figura 6.- Sistema de datos ecológico-silvícolas, información recabada.

Título del Sistema: Sistemas de Cómputo para Inventario Forestal Continuo

Autor: Dirección General del Inventario Forestal.

Descripción: es un sistema en Batch integrado de varios programas, cada uno previendo la información que otro pueda necesitar de él.

Los programas desarrollados son básicamente tres:

Programas de verificación.- Consta de cinco subprogramas que permiten verificar omisiones y duplicidades, al igual que los rangos correspondientes a las variables.

Programas de creación de archivos.- Su función consiste en grabar los datos en dispositivos de acceso directo, como los discos magnéticos, para facilitar su manejo.

Programas de producción.- Proporciona la información intermedia y final, prevista para cada sistema.

Protección de archivos. Dado el valor de los datos manejados, es muy importante su conservación, asímismo, la información captada en la siguiente remedición, es necesario archivarla en cintas o discos magnéticos, por duplicado, almacenándolos en diferentes lugares.

Dentro de este sistema de procesamiento, se tienen a su vez otros subsistemas, destacando el de tablas de volúmenes que ya describimos.

Otro subsistema que es determinante en un IFC, es aquel para la cuantificación y calificación del arbolado comercial, de incorporación y renuevo. El paquete se encuentra constituído por nueve programas de cómputo, que al igual que el subsistema de tablas de volúmenes, permiten efectuar la verificación y corrección de datos, obtención de resultados finales, y la conservación de archivos.

Las fases desarrolladas de mayor importancia son:

Frecuencias de arbolado por especie. Permite rectificar o ratificar las agrupaciones previstas, y para aquellas especies presentes no consideradas, definir la tabla con la que se han de cubicar y al grupo al que se han de integrar.

Información por sitio. Para el IFC esta es una información básica, ya que es el punto de partida que permitirá evaluar la dinámica del bosque; tratándose de este sistema que es aplicable a la primera remedición o establecimiento de la metodología; se obtienen datos de ubicación, cuantificación, potencialidad y calificación del arbolado comercial (sitios de 1,000 m^2); la cuantificación y calificación del arbolado de incorporación (sitios de 400 m^2), y la cuantificación del renuevo (sitios de 80 m^2) (fig. 7).

Datos de entrada: En la Dirección General del Inventario Forestal, se emplea y se recomienda el uso de formas impresas en papel para la captación de los datos en los sitios de 1,000, 400 y 80 m^2, puesto que presentan las siguientes ventajas:

- Permiten la mayor captación de variables por registro, ya que un diseño de tarjetas, implica un mayor número de formatos a emplear y más anotaciones, respecto a los datos de control para cada uno de ellos, con la consecuente fuente de error.

- Facilitan la toma de datos por parte del personal de campo.

- Se facilita la verificación y corrección (fig. 8).

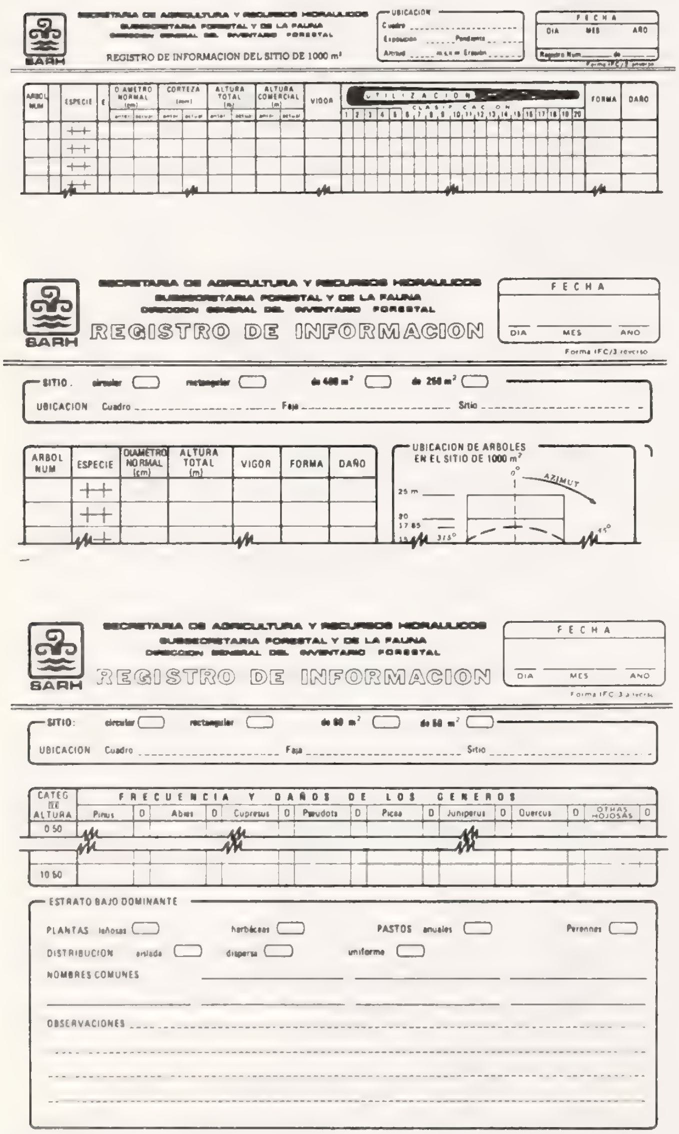

Figura 8.– Formas utilizadas en el registro de información, dentro del sistema de cómputo para IFC.

Como se puede apreciar en la figura 8, los principales datos de entrada son los siguientes:

Para el sitio de 1,000 m^2 se toman los datos de control, definitivos para la relocalización en la fase de remedición, fecha, entidad, municipio, línea de vuelo, número de fotografía, etc. La información técnica se refiere a: árbol número, unidad taxonómica, diámetro, altura, uso de la madera, forma y daño.

Para el sitio de 400 m^2 la información de entrada es: árbol número, unidad taxonómica, diámetro, vigor, forma y daño.

En el sitio de 80 m^2 los datos de entrada son: categoría de altura, amplitud de la categoría y la frecuencia de géneros botánicos del repoblado.

Datos de salida: Con apoyo en la información generada en los listados de frecuencia y de resultados por sitio, se obtienen estos resúmenes:

Frecuencias en diámetro y altura de arbolado comercial por hectárea.

Cuantificación, potencialidad y calificación del arbolado comercial por hectárea.

Frecuencias de la calificación de vigor y forma, por hectárea del arbolado comercial y de incorporación.

Frecuencias de la calificación de daño por hectárea para arbolado comercial y de incorporación.

Frecuencias por hectárea de renuevo por categoría de altura.

Sistemas de Procesamiento de Datos para Inventarios de Zonas Aridas

En virtud de que la Dirección General del Inventario Forestal ha iniciado el inventario nacional de las zonas áridas y semiáridas, se han llevado a cabo diversos estudios tendientes a definir las metodologías más adecuadas que permitan determinar las características cualitativas y cuantitativas de la vegetación que se desarrolla en estas zonas. Los principales esfuerzos se han dirigido a los aspectos de muestreo en el terreno y a la representación cartográfica. Con relación a este último punto, el Inventario Forestal ha venido estudiando, en aquellas entidades que presentan condiciones de aridez, la vegetación en cuanto a sus agrupaciones más comunes, esto es, matorrales micrófilos, rosetófilos y crasicaules. La información se complementa con el señalamiento del tipo de fisiografía existente; planicie, ladera, lomerío, etc.

Sistemas aplicados en estudios cartográficos con sensores remotos

Simultáneamente a la elaboración de la carta forestal de las zonas áridas, se realizan estudios con sensores remotos desarrollados en la década de los setentas, específicamente con imágenes Landsat. Para la obtención de los sistemas automatizados, que permitirán analizar dichas imágenes, se acordó un convenio de cooperación entre el Inventario Forestal y el Centro Científico de I.B.M. de México. A continuación se hará referencia al sistema ERMAN II y a la metodología aplicada en un estudio piloto para elaborar el mapa de vegetación en una porción de los estados de Tamaulipas y Coahuila.

Descripción del sistema: El ERMAN II es un sistema interactivo, originalmente desarrollado por IBM para la NASA, bajo el nombre de ERIPS. Está compuesto de una serie de programas cuyo objetivo es el desarrollo de una gran variedad de funciones, relacionadas con el procesamiento de imágenes digitales.

Cada uno de estos programas es controlado por un sistema supervisor y su objetivo es establecer la comunicación con las terminales y proceder a la ejecución de los programas según lo requiere el usuario.

Las actividades de mayor relevancia del sistema ERMAN son: programa de carga, despliegue de imágenes en el monitor, reconocimiento de patrones por clasificar, cálculo de la probabilidad de error y finalmente, la clasificación propiamente dicha (fig. 9).

Programa de carga: El programa de carga se ocupa de pasar las imágenes, de cinta a disco y viceversa. El sistema ERMAN, en todas sus aplicaciones usa imágenes almacenadas en discos por ser este proceso más

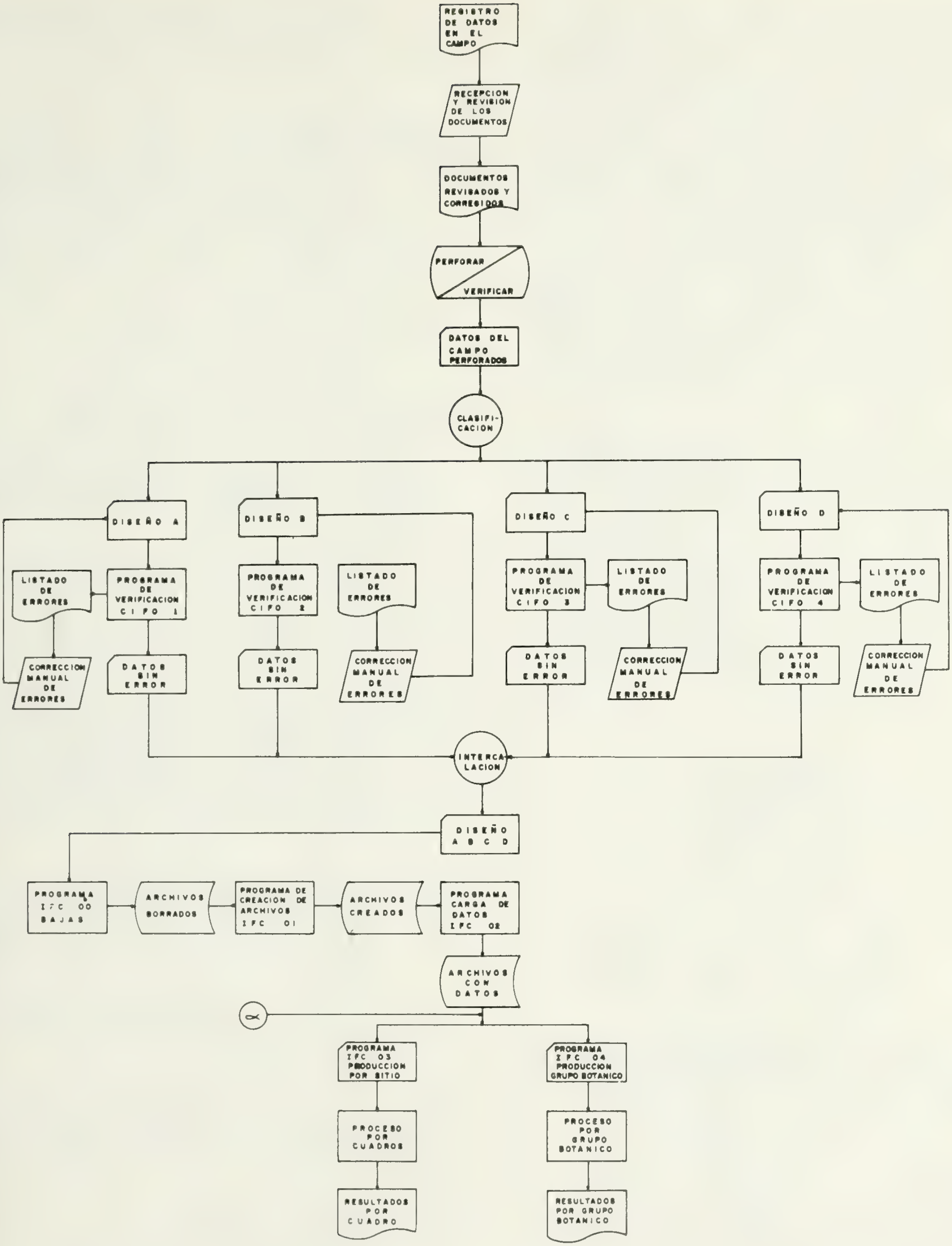

Figura 7.-- Flujo de datos en el sistema de cómputo para inventario forestal continuo.

rápido. Las cintas se utilizan para grabar la información considerada importante, con el objeto de conservarla.

Despliegue de imágenes en el monitor: Al desplegar la imagen se puede utilizar una, dos o como máximo tres bandas, pudiendo escoger y asignar uno de los tres colores base: rojo, verde y azul. Estas se pueden obtener amplificadas o reducidas; mediante el cálculo de un histograma son visualizadas con mayor o menor contraste de colores y tonos.

Reconocimiento de patrones: Mediante este programa se efectúa la clasificación automática, ya sea en forma supervisada o no supervisada. En el presente trabajo se usó la forma supervisada, es decir, se señalo al computador los conceptos por diferenciar: matorrales micrófilos, rosetófilos y crasicaules, además de pastizales, cuerpos de agua, etc.

La primera fase de este programa es la definición de campos. Al respecto, existen dos tipos de campos a definir:

a) Campos de entrenamiento.- Su objetivo es permitir el cálculo de estadísticas que se utilizarán en el algoritmo o fórmulas matemáticas para la clasificación. Como su nombre lo indica, -- procede a entrenar a la computadora para posteriores clasificaciones de los tipos de vegetación elegidos.

b) Campos de prueba.- Sirven para efectuar la clasificación a partir de las estadísticas calculadas en los campos anteriormente citados.

Probabilidad de error: Es un análisis previo a la clasificación que efectúa una comparación estadística de los campos de entrenamiento entre sí y respecto a un testigo o fuente confiable; tiene por objeto comprobar la correcta definición de los campos de entrenamiento.

Mediante el análisis de los resultados de la probabilidad de error, se pueden determinar las clases que presentan mayor dificultad para una buena clasificación.

Clasificación: Una vez entrenada la máquina se procede a segregar las áreas características similares, de acuerdo a los conceptos por separar.

Para efectuar la clasificación se utilizan dos parámetros, que ayudan al sistema a obtener una mejor definición de los tipos de vegetación por clasificar y detectar.

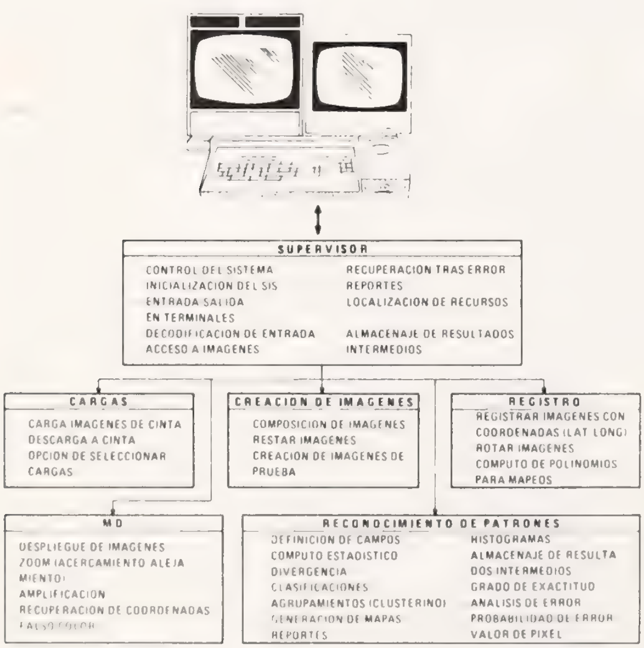

Figura 9.– El sistema ERMAN se emplea en los estudios cartográficos con sensores remotos.

a) Porcentaje de área ocupada por cada clase. Durante la definición de los campos o muestras de prueba sobre una porción de imagen de satélite, se calculan los porcientos de cobertura para cada clase. Con estos valores la máquina hace una ponderación que le facilita efectuar la clasificación con más elementos de apoyo.

En caso de que el usuario no dé los datos de estos porcentajes de área, el computador considera para sus cálculos, que todas las clases ocupan un porcentaje igual en la imagen.

b) Definición de fronteras. Una vez realizados los cálculos anteriormente citados, se procede a determinar nuevos parámetros, cuando en los límites de dos rodales exista confusión por traslape. De esta forma se indica al programa el grado de exigencia con que se deben clasificar aquellos pixels donde existe duda. Recordamos que un pixel es la unidad mínima diferenciable en una imagen.

Efectuada la clasificación, los resultados pueden obtenerse de dos maneras:

Imagen clasificada en el monitor, donde es posible asignar colores a cada tipo de vegetación.

Mapa de caracteres, que se obtiene en forma impresa con los símbolos de cada clase determinados previamente.

Resultados obtenidos en la aplicación del sistema:

No obstante que los avances logrados con esta metodología se -- consideran como experimentales, podemos adelantar como conclusiones los siguientes puntos en particular:

A un tipo de matorral en el terreno, corresponde en una imagen de satélite un determinado color y tono, dados por una cierta longitud de onda. Se pretende establecer una correlación lógica entre éstos y su realidad.

Siendo perceptibles a simple vista, los tipos de vegetación, se estima la alta posibilidad de utilizar métodos automatizados para su detección y clasificación en tiempos breves y a bajo costo.

El programa de carga y el despliegue de imágenes resultó adecuado a las necesidades del presente trabajo; en cuanto al reconocimiento de patrones, los campos de entrenamiento siempre fueron tres por cada clase. La probabilidad de error resultó un elemento sumamente valioso de análisis, tanto de cada clase, como de éstas entre sí. En relación a los parámetros previos a la clasificación -- puede decirse, que el denominado porcentaje de área fue aprobado en sus dos alternativas, lo mismo puede decirse del grado de exigencia; estas modificaciones se reflejan notablemente en la clasificación.

Cartográficamente, la clasificación automática es correcta, lo cual se comprueba al sobreponer un positivo en acetato de una carta confiable de la misma escala, sobre el mapa de caracteres obtenido de la aplicación del sistema. Estadísticamente y según el parámetro denominado "probabilidad de acierto" los valores fueron mayores del 75 por ciento en promedio de todos los conceptos.

Con los primeros resultados obtenidos, la hipótesis planteada quedó demostrada. Las claves y los conceptos son correctos y se adaptan a las diferentes condiciones del terreno clasificado.

Equipo empleado: Una computadora IBM modelo 360/65, con 512 K posiciones de memoria.

Una terminal RMTEK GX-100-B, conectada por medio de una interfase a la computadora. Esta terminal cuenta con dos monitores Conrac. El primero, de colores, para el despliegue de imágenes, y el segundo, en blanco y negro, para la comunicación con el sistema que en conjunto, con un teclado y un manipulador del cursor, permite usar interactivamente la computadora.

Contactos para información técnica.

Centro Científico de América Latina I.B.M.
Cantil No. 150
México 20, D. F.

Dirección General del Inventario Forestal
Departamento de Fotogrametría y Fotointerpretación
Av. Progreso No. 5,
Coyoacán, D. F.

Otros sistemas para el Análisis de Imágenes de Satélite

En términos generales, la investigación y el desarrollo de técnicas y procedimientos de cómputo para analizar imágenes de satélite, tiene como finalidad poder detectar, en forma automatizada, diferentes elementos de la superficie terrestre fotografiada, entre los que se incluyen las características de las asociaciones vegetales de las zonas áridas.

El sistema visto y los que mencionaremos brevemete, tienen sus bases sobre las ciencias de la computación, en particular en el reconocimiento de formas, el análisis numérico y el procesamiento digital de imágenes.

Sistema Percepción Remota CIMAS—UNAM

Título corto: Proyecto P. R.

Elaboró: Adolfo Guzmán A., Investigador del CIMAS.

Descripción: El sistema PR es interactivo, puede servir a múltiples usuarios a la vez, y ha sido implementado en la computadora Burroughs B 6700 del CSC—UNAM. Tiene la capacidad de formar subimágenes de tamaño arbitrario, según las necesidades de analizar superficies determinadas. Pueden almacenarse en disco o cinta, así como de crear nuevas imágenes a partir de anteriores; elabora un banco de datos, con los valores contenidos en los temas bajo análisis.

El sistema PR puede efectuar clasificaciones supervisadas, es decir, dirigidas a identificar ciertos elementos, con todas o con alguna de las bandas de cada imagen.

Tiene la facultad de señalar si la información terrestre es inconsistente o contaminada (confusa); puede detectar el porcentaje de errores en su clasificación, y es resistente del usuario, es decir, detecta y sugiere correcciones a la mayoría de los errores del operador.

La salida de información es por multi-impresión y se complementa con una impresora de tonos grises y una pantalla monitor a color.

El sistema se ha aplicado a nivel experimental en detección de trigo en el Valle del Yaqui, en la actualización de cartas temáticas y topográficas, en estudios de la vegetación del estado de Veracruz.

Proyecto: Sistema de Procesamiento Automático de Imágenes de Satélite

Título corto: Proyecto PAIS.

Descripción: Este sistema dio origen a las actividades del proyecto PR, por lo que existe gran semejanza entre ellos. Está basado en técnicas de reconocimiento de formas y análisis digital de imágenes y fue desarrollado en la antes Comisión Nacional del Expacio Exterior (investigador Dr. Jorge Valerde).

Otros sistemas que podemos señalar a nivel de mención son:

Proyecto SRH, de la antes Secretaría de Recursos Hidráulicos, -- consta de varios programas de cómputo para el estudio del uso del suelo de la República con imágenes de satélite.

Sistema LARSYS. Elaborado en la Universidad de Purdue, E.U.A., está escrito en Fortran IV y es de uso muy extenso. La NASA lo usa en sus investigaciones agrícolas.

Finalmente, el ERIPS es un sistema hecho por IBM, requiere para su aplicación de máquinas grandes, por ejemplo 360/50 o 360/65 y de monitores especiales.

Sistemas de cómputo para datos de campo en inventarios de zonas áridas.

Como hemos visto, las metodologías para inventarios forestales en nuestro país, presentan mayores adelantos en los bosques de clima templado-frío y en menor escala en las selvas de clima cálido-húmedo. Para las zonas áridas y semiáridas, las técnicas de cuantificación desarrolladas, son más modestas en su evolución. Esta condición es fácil de suponer que tiene su origen en la comercialidad de los productos que genera cada región climática señalada, con la correspondiente desventaja de las zonas áridas.

Para la elaboración del presente documento se recurrió a diversas dependencias relacionadas con el estudio de las zonas que nos ocupan,y se encontró que la mayoría de los trabajos realizados se refieren casi exclusivamente al análisis de las características cualitativas. Respecto a las estimaciones de volúmenes, tablas de conversión, etc., se apreció que únicamente dependencias de la Subsecretaría Forestal y de la Fauna, llevan a cabo el estudio cuantitativo de las zonas áridas, principalmente en la fase de investigación, experimentación y adecuación metodológica. La Dirección General del Inventario Forestal desarrolla técnicas encaminadas a definir los procedimientos, para estimar la cuantía y las características de la vegetación de estas zonas; el proyecto se inició en 1978 y a la fecha se tienen resultados de los métodos que es factible aplicar en la captación de las muestras en el terreno. Asímismo, se ha definido el contenido y presentación de la carta forestal de las zonas áridas, la clave de fotointerpretación adoptada se apoya básicamente en la composición florística y en la fisiografía del terreno. Para el efecto se emplearán valiosos materiales ya existentes como son las fotografías aéreas y cartas producidas por la Dirección General de Geografía del Territorio Nacional, antes DETENAL, las cartas Sinópticas de la Dirección de Agricultura de la SARH, y las cartas forestales del Inventario Forestal.

Dentro del proceso cronológico de la definición de metodologías, los sistemas de procesamiento de datos para zonas áridas que aplicará la Dirección General del Inventario Forestal, se encuentran en su etapa incipiente. Se tiene el esquema de los datos de entrada para el sistema y se cuenta con el planteamiento aproximado de los datos de salida a que se quiere llegar, mismos que quedarán definidos por las necesidades del usuario.

A este respecto, el Instituto Nacional de Investigaciones Forestales, dentro de su Departamento de Evaluación de Recursos, ha venido trabajando en el desarrollo de los sistemas mencionados. Los logros obtenidos han permitido efectuar ensayos que han demostrado la aplicabilidad de los programas que integran el sistema; a continuación se presenta una breve descripción de los mismos:

Título del Sistema: Sistema de Procesamientos para inventarios de zonas áridas

Autor: Instituto Nacional de Investigaciones Forestales.

Elaboró: Departamento de Estadística y Cómputo - INIF.

Descripción: es un sistema en Batch compuesto por varios programas relacionados entre sí, para la obtención de valores de los conceptos bajo estudio, la correlación de estas variables y la elaboración de tablas de rendimiento.

El computador empleado es una máquina Burroughs B/6700 y los programas están escritos en lenguaje Fortran IV.

Objetivos: mediante este sistema se obtiene la información numérica de los conceptos "yuca" y "cardón", relacionados con diferentes variables como diámetros, alturas, tamaño de rosetas, etc.

Descripción de los programas:

1. Obtención de los valores para los conceptos "yuca" y "cardón", referidos por unidad de superficie y estrato. Mediante este programa se obtienen para las especies, ya antes mencionadas, los valores medios por hectárea, por sitio, por estrato y totales, en cuanto a volumen, diámetro, alturas, número de hojas, volumen fustal, frecuencias, número de ramas, número de rosetas, longitud de rosetas, diámetro de rosetas, número de renuevos y número de brotes.

2. Correlación de variables por sitio, por estrato, por hectárea y totales de yuca. Tiene por objeto encontrar la relación numérica existente entre la altura total y el diámetro del fuste, entre la altura total y el número de hojas de la roseta. Para lograrlo se aplicó una regresión lineal simple y múltiple, en donde el número de individuos actúa como variable dependiente y la altura total y el diámetro son las variables independientes.

Este programa establece la correlación entre dos conceptos compatibles, para obtener tablas de doble entrada, de la siguiente forma:

Peso verde de las hojas de rosetas de yuca, en función del diámetro y longitud de las rosetas.

Peso de fibra seca en función, también del diámetro y de la longitud de las hojas de la roseta.

Para comprobar la bondad de los tres programas mencionados que integran este sistema, se efectuaron las siguientes pruebas:

1. Pruebas de comparación de los resultados obtenidos, contra el testigo, mediante el método de Dunnet, para determinar las diferencias significativas.

2. Análisis de varianza, tendiente a obtener los niveles de significación de los esquemas planteados y los testigos, mediante - - pruebas de Scheffe.

3. Finalmente, se analizan los niveles de eficiencia obtenidos en cuanto a los tiempos de caminamiento entre sitios, conglomerados y fajas, así como del tiempo de levantamiento de los datos por sitio.

Estos estudios se efectuaron en una superficie de 400 ha en Baja California Sur, en el municipio de Todos Santos.

CONCLUSIONES Y RECOMENDACIONES

1. El vertiginoso desarrollo, en materia de equipo y técnicas de cómputo electrónico, permite día a día lograr una mayor agilidad, versatilidad, seguridad y disminución de costos en el procesamiento de datos.

2. Los sistemas de cómputo desarrollados para inventarios forestales tradicionales, ya sea a nivel nacional o de manejo en áreas arboladas, satisfacen las necesidades de los usuarios. Asímismo, existen los elementos humanos y materiales para la ejecución del paquete, en cualquier centro de cálculo del país.

3. En inventarios forestales periódicos o continuos, se han elaborado adecuadamente, los sistemas de procesamiento de datos correspondientes a la fase de implantación de los sitios permanentes de muestreo. A la fecha se cuenta con el diseño conceptual de los programas que deberán aplicarse para procesar y comparar la información, producto de las mediciones subsecuentes de dichos sitios. Por lo tanto, es urgente que las Direcciones de Información y Sistemas Forestales y del Inventario Forestal, convengan la forma de elaborar el sistema para las remediciones de un IFC.

4. En cuanto a las imágenes de satélite empleadas para el estudio de la vegetación de zonas áridas, se ha demostrado a nivel experimental, que la metodología es eficiente, siempre y cuando se complemente el análisis automatizado, con la experiencia y conocimientos del fotointérprete.

5. En la etapa de análisis de fotografías por computadora, dado lo interdisciplinario de la percepción remota, todo programa en esta área debe probarse, ajustarse y adaptarse a un conjunto de criterios de programación, relacionados con la verdad en el terreno. Por lo tanto, este trabajo debe efectuarse por un grupo integrado de técnicos expertos en sistemas y por los ingenieros o biólogos del área de aplicación.

6. Debido a que el estado actual del análisis automatizado de imágenes multiespectrales, en cualquier paquete no probado, es altamente experimental, se recomienda a los usuarios, recurrir a sistemas que hayan demostrado con hechos su confiabilidad. Esta recomendación es aún más importante, si se desea "comprar" el paquete, que normalmente el fabricante vende en conjunto (Software y hardware).

7. Se recomienda impulsar el inventario nacional de las zonas áridas, a cargo de la Dirección General del Inventario Forestal; para el efecto se cuenta con la valiosa participación del Instituto Nacional de Investigaciones Forestales, donde técnicos e investigadores de ambas dependencias, trabajan para definir las metodologías de muestreo, y de mediciones de campo por aplicarse, asímismo, se desarrolla el sistema de procesamiento de datos, que proporcionará los valores cuantitativos de las zonas áridas y semiáridas del país.

ABSTRACT

This paper describes some of the computing systems most commonly used in Mexico for the quantification of forestry resources.

In this presentation, the following information is offered:

--Title
--Author
--Description
--Objectives
--Entry data
--Output data
--Computer model
--Applications
--Additional information
--Sources of technical information

The data provided was obtained from these agencies which are responsible for the study of natural resources, especially for their qualification, quantification and mapping. This paper intends to offer an objective summary of the most common processing systems for inventories in Mexico; for further information, the sources for the corresponding technical consults are pointed out in each case.

FIDAPS - A Forest Inventory Data Processing System for the Tropics[1]

K.D. Singh and J.P. Lanly[2]

Abstract - FIDAPS has been developed by the Forestry Department of the Food and Agriculture Organization of the United Nations to enable tropical countries to make use of the capabilities of electronic data processing in forest inventory.

The system permits a wide range of choices regarding sampling design, volume and quality estimation procedures used in the tropics and accepts input data coded in a variety of field forms.

It requires a maximum memory of 128K bytes, though most of the programmes can be run with only 64K bytes. In addition to normal card reader and line printer, availability of capability to handle 3 data sets (or files) at a time is assumed. Programmes are written in FORTRAN IV (G-level) in the form of small modules which makes their understanding easy.

Data processing is carried out in five phases consisting of data preparation (office checking, punching/verification), data editing (which ends with clean input data file), file updating (adding volume and other information to clean input file) and simultaneous creation of master and summary files, statistical analysis (consisting of calculation of mean and standard error for number of stems and volume by species and diameter classes at various reporting levels, e.g. stratum, inventory unit and the whole project area) and report generation (producing a set of standard tables).

The complete package of programmes can be learned by an average programmer in 2-3 weeks time. FIDAPS has been documented in three volumes, (viz): Users Guide, System Documentation and the third one containing complete programme listings. With the help of short training sessions and consultancy missions, FAO is now assisting in the transfer of the software to the tropical countries.

INTRODUCTION

FIDAPS[3] is the acronym of a computer software package developed by FAO under a SIDA[4] Trust Fund to facilitate computerization of forest inventory data processing in the tropics. Its development was motivated by the observation that many forestry institutions in the tropics were not able to take full advantage of electronic data processing capabilities due to the lack of suitable software corresponding to their needs and/or lack of trained manpower in this field.

Any electronic data processing system, if it is to be of general use in the tropics, should take recognition of some basic facts:

(i) The data processing environment is highly diverse. This refers to sampling design and

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[1]Paper presented at the Arid Land Resources Inventories Workshop, La Paz, Mexico

[2]K.D. Singh is the Forest Resources Survey Officer, FAO, Rome. J.P. Lanly is the Coordinator, FAO/UNEP Tropical Forest Resources Assessment Project, FAO, Rome

[3]In full form it stands for Forest Inventory Data Processing System

[4]Swedish International Development Authority

mensurational techniques used for inventory as well as to the types of computer models employed.

(ii) There is a relative lack of specialization in this field, which makes it imperative to develop a detailed documentation preferably in the form of a manual giving step by step information and to disseminate it with the help of short training courses or consultancies.

The above considerations have served as guiding principles in the design of FIDAPS, as described in the following sections.

1. SYSTEM SPECIFICATION

1.1 Forest Inventory Alternatives Considered

FIDAPS includes a variety of options related to sampling design, volume estimation, stem quality appraisals and data recording layouts generally used in the tropics.

1.1.1 Sampling Design Options

A list of field sample designs which can be processed by the system is given in Figure 1. The sampling units in one-stage sampling designs (or the secondary sampling units in two-stage designs) can be areal elements or points (sampling of trees with probability proportional to their basal area). They can also be clusters of areal elements or points. Sampling units or recording units may have up to three different unit areas according to diameter categories (or two different basal area factors if it is point sampling).

1.1.2 Volume and Quality Assessments Choices

The number of stems are converted in gross volume, either by volume tables or specified volume equations or taper functions which are by "parameter cards". Quality estimation procedures can be those made externally, by logs of equal absolute or relative length, or by logs of unequal length or for whole tree. Internal quality estimation procedures using drilling devices are also taken into account.

1.1.3 Field Data Recording Possibilities

Four alternatives for data recording have been included. Two extremes are described here. In the simple one trees are enumerated by species and diameter classes; in the most complete one a number of parameters are measured and appreciated on every tree. For each recording unit, identification data and stand and site characteristic data can also be recorded which are then also processed.

1.2 Computer Specifications

FIDAPS makes a minimal demand on the type and size of computer. The programming language chosen is FORTRAN IV, which is perhaps the most universal scientific programming language. Maximum memory size required is 128K bytes; most of the programmes, however, require less than 64K bytes. All data sets (or files) are sequential in nature and not more than 3 data sets are used at the same time. Thus, a tape oriented system would require a maximum of 3 tape drives. In addition to a FORTRAN compiler, availability of a short/merge routine is assumed.

2. SYSTEM STRUCTURE AND FUNCTIONS

2.1 System Description

A broad description of the system with the help of a flow-chart is given in Figure 2. According to this the data processing activities can be distinguished into the following five phases:

2.1.1 Data Preparation

This phase converts field forms to standard input records. There is one series of record types for standing trees and another one for felled trees. Various types of data conversion systems could be used, e.g. punched cards (80 positions), diskets or disks.

2.1.2 Data Editing

This phase includes sorting of the standard records into a required sequence, computer editing, storage of data on files and the correction of errors. At the end of phase 2 one gets the clean input data file.

2.1.3 File Updating and Creation of Master and Summary Files

The main function of this phase is to calculate the tree volumes by species, diameter class and quality class for the updating of the clean file to get a master file. Species group and diameter group codes are also added to this file through parameter cards. Any recalculation for the changing of volume calculations, species grouping, etc. must start from this phase.

The second function of this phase is to generate the summary files, which then are used for sampling error calculation and the basic tabulations. This file is compiled at the sampling unit level by species or species groups, containing the following main data:

- sampled areas ("proportions")
- volumes per area unit by diameter class
- stems per area unit by diameter class.

2.1.4 Statistical Calculations

This phase calculates the mean and sampling error for number of stems and volume by species or species groups and diameter or quality classes at the inventory unit, stratum or project level if required. Stand and stock tables can then be printed from the output file of this phase.

2.1.5 Report Generation

This phase produces a set of standard stand and stock tables with or without sampling error values at various reporting levels, e.g. a stratum, an inventory unit or the whole project area.

2.2 System Use

The system is guided with the help of parameter cards which direct programmes to carry out the required calculations corresponding to specified choices made with regard to inventory design and mensurational techniques. Most of the data processing is handled in this way. There is scope for inclusion of sub-routines specially written by the user to perform specific operations on data not included in the system.

Special effort has been made to make the constituent programmes of FIDAPS readable; first by writing them in the form of small modules and secondly by adding plentiful comment cards. The user is thus encouraged to modify or add some instructions and interact with the system.

2.3 System Output

The system output can be distinguished in intermediate or final output. Examples of the first category are error messages, intermediate data files, etc. These are useful mainly to the system analyst/programmer. The final output of FIDAPS, which interests users the most, consists of the following:

(a) Data Files

(i) The master file which includes the original input data as well as the data generated by the system.

(ii) The summary files described earlier.

(iii) The file containing the results of statistical calculations.

(b) Print output

(i) Area tables and species frequency tables generated in the edit phase from the clean data file (optional).

(ii) Results of statistical analysis.

(iii) Stand and stock tables (i.e. mean volume/number of stems by species and diameter classes, standard error estimates for the mean volume/number of stems by species and diameter class).

2.4 System Restrictions

The restrictions are of two types: the first arising from the provided options in respect to the inventory design or volume and quality estimation procedures. These have been described earlier; the second corresponding to the dimension of various variables which is dependent on the size of the computer memory. Some examples are:

- maximum number of species:	800
- maximum number of species groups:	30
- maximum number of diameter classes:	21
- maximum number of diameter groups:	6
- maximum number of quality classes:	5

The above restrictions were made from a desire to accommodate various programmes in a small computer memory.

3. SYSTEM INSTALLATION AND USE

The installation and the use of FIDAPS is being facilitated by the system documentation, training courses and consultancies.

3.1 System Documentation

This includes:

(i) a user's guide introducing the system to the average forester/user;

(ii) a system manual providing detailed and step by step guidance to the system analyst/programmer for carrying out various data processing activities; and

(iii) full programme listing, which is given as a separate volume.

3.2 Training Courses and Consultancies

These are being organized by FAO in various forms such as:

(i) short familiarization seminars of 2-3 days at the national level; or

(ii) 2-3 week international/national training courses to experienced inventory specialists and programmers; and finally

(iii) consultancies as part of on-going field projects.

Accomplishments up to 1979 include two short familiarization seminars, one in Brazil and the other in Chile; a two-week training course for selected programmers of Asia and the Pacific Region; and application of the system to two preinvestment forest surveys in Indonesia and Brazil.

In 1980 the programme includes installation of the system and training of the counterparts in the Philippines and Brazil, and organization of familiarization seminars to a wider audience in these countries.

During 1981 proposals have been formulated to organize an inter-regional course at FAO, Rome, to train about 10 specialists and to install the system in a few tropical countries either with the help of trained national staff or through

international consultants.

4. FUTURE DEVELOPMENT

With respect to the future there are two ideas:

(i) To continue the dissemination of FIDAPS through documentation, training and consultancies, and carry out minor system updating activities based on accumulated experience.

(ii) To develop additional routines for data storage, retrieval and processing as part of FAO programme on forest resources assessment and monitoring of changes on a national, regional or world-wide basis. Some preparatory action has been initiated on this subject during the current year. No firm date, however, can be given at present for the completion of the task, as the latter is now in the formulation stage only.

5. CONCLUSION

FIDAPS has been developed with special reference to forest inventory data processing problems of tropical countries. The system is, however, general enough and could be used anywhere. In the case of large computer installations there may be possibilities of further improving the cost-effectiveness of the system by modifying some input/output routines to take advantage of facilities locally available.

It is further expected that, as FIDAPS will be used more and more, there will be need to periodically amend and improve the system as to adapt it to newly arising situations. It is also hoped that FIDAPS will, in the long run, lead to some standardization of inventory procedures and data collection, and thus promote regional and interregional studies.

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RESUMEN

El FIDAPS ha sido preparado por el Departamento de Montes de la Organización de las Naciones Unidas para la Agricultura y la Alimentación para permitir a los países tropicales aprovechar las posibilidades que ofrece la elaboración electrónica de datos para la inventariación forestal.

El sistema permite muchísimas opciones en el diseño del muestreo y en los procedimientos de estimación del volumen y de la calidad de la madera, y acepta además datos de entrada codificados en diversos tipos de formularios.

Basta una memoria con una máximo de 128K bytes, aunque para la mayoría de los programas son suficientes 64K bytes. La computadora, además de disponer del lector normal de tarjetas y de impresor en línea, la de poder tratar contemporáneamente tres series de datos (ficheros). Los programas están escritos en FORTRAN IV (nivel G), en forma de pequeños módulos, lo que facilita su comprensión.

La elaboración de los datos se hace en cinco fases: preparación de los datos (control en la oficina, perforación/verificación); edición de los datos (al final de la cual se obtiene el fichero en limpio de datos de entrada); actualización del fichero (adición de información sobre volumen, etc. al fichero en limpio de entrada) y creación simultánea de ficheros master y resumidos; análisis estadístico (cálculo de la media y el error estándar del número de troncos y el volumen por especies y categorías de diámetro, en los diversos niveles a los que se refieren los datos, como, por ejemplo, estrato, unidad del inventario y área total del proyecto), y tabulación de los resultados (una serie de tablas estándar).

Un programador medio puede aprender la serie completa de programas en 2 ó 3 semanas. La documentación necesaria para el FIDAPS se ha recogido en tres volúmenes: guía del usuario, documentación del sistema y listados completos del programa. La FAO está ahora facilitando la transferencia de este software a los países tropicales mediante breves cursos de capacitación y misiones de consultores.

Portable Data Recorders[1]

Roy C. Beltz [2]
George C. Keith [3]

Electronic data recorders have been successfuly applied in field activities of the continuous forest survey. A new data-entry system minimizes the transition trained cruisers must make from tally sheets to digital entry. Telecommunications, data capture, and subsequent processing are reliable and efficient. Keypunching costs, time requirements, and associated errors are eliminated. The recovery are light, compact, and can communicate with a variety of computer hardware.

Introduction

One activity common to all inventories is the collection of information. Advances in electronics technology hold great promise as cost-effective means of capturing inventory information. Today, we'll describe the application of portable data recorders in the continuous forest inventory of the Mid-south United States. We'll include some background on the survey activity, our experience with data recorders in the field, and some pros and cons of using data recorders.

Forest survey teams have been measuring plots and tediously writing numbers on tally sheets since 1933. At last, a workable alternative is available. Data recorders, electronic devices similar to small hand-held calculators, now encode survey data right at the forest scene. The value of such an alternative becomes obvious in light of the overall forest survey mission.

In 1928, the Mc-Sweeney-McNary Act authorized a forest survey to assess timber resources on all lands, both public and private. These surveys--with pencil and paper--began in 1933.

Each state in the South is inventoried at least once every 10 years. Estimates of timber volume are derived by measuring field sample plots located at three-mile intervals. Many attributes are recorded so analysts may assess volume, quality, species, growth, and ownership of the timber resource. This information is used to develop long-range policies and programs to ensure a continuing supply of wood.

This activity, originally labeled "Forest Survey," continues today as Renewable Resources Evaluation (RRE). New laws such as the Forest and Rangelands Renewable Resources Planning Act of 1974 and the Renewable Resources Research Act of 1978, have expanded the survey role to nontimber forest and rangeland resources assessment.

Gathering, compiling, and analyzing this information is a never-ending mission. The effort is divided into seven major geographical areas of the United States, one of which is the Midsouth--Alabama, Arkansas, Louisiana, Mississippi, Oklahoma, Tennessee, and Texas. In the Midsouth alone, thousands of sample plots are remeasured annually. Over the years, we have tried to find more efficient ways of dealing with this flow of information. Punched cards and accounting machines were put into use in the late 1950s. Computer processing of punched cards began during the 1960s. Until 1976, material was sent to a computer center and results were returned by mail.

Since then, we have installed computer terminals for remote access to computers and finally, we have installed a mini-computer to process our own data.

For those not familiar with data processing, a brief discussion of routine procedures illustrates problems common to nearly every computer user. Through advances in computer technology, vast amounts of information can now be processed quickly and voluminous output produced in print, microfiche, tapes, and other media. To feed these powerful processors efficiently operators must somehow automate the input of information. In 1890 Herman Hollerith introduced the concept of interpreting holes in cards. By various arrangements of the holes in each of 80 columns, each column can represent a digit, letter, or special character. Machines were developed to punch and to interpret the holes. Though many advances have been made in data entry, most information processed through a computer originates as holes in cards.

A perennial problem has been editing the tally sheets and punching data cards from them. Each time the information is handled, the opportunity for human error creeps in. Tally sheets are often exposed to moisture (rain, dripping bushes, perspiration) and insects. As a result, entries may be obscured and misinterpreted. Additional errors may be

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1 Paper presented at Arid Land Resource Inventories: LaPaz, Mexico.

2 Project Leader, Renewable Resources Evaluation, Southern Forest Experiment Station, USDA Forest Service, New Orleans, Louisiana.

3 Computer Programmer, Renewable Resources Evaluation, Southern Forest Experiment Station, USDA Forest Service, New Orleans, Louisiana.

introduced during keypunching. Such factors detract from the quality of the information coming into the data-processing system.

In search of alternatives to tally sheets, we tested tape recorders and portable card punchers, but problems remained. Now, a solid state memory device promises to eliminate transcription and keypunching entirely. Although several problems had to be overcome, and some remain, plot information may now be entered directly while working in the woods. This information is then sent by telephone to base equipment in New Orleans.

Data recorders were designed for special inventory needs of supermarkets and warehouses. Units are light and compact, but the display is limited to 12 characters. A character is a letter, digit, or special symbol such as " + " or " = ", and a character is equivalent to a column on the 80-column punch card. While this is adequate for stock numbers and quantities, recording the many plot and tree items on survey samples required some innovations.

We commonly think of data in 80-column cards, a holdover from the past. But by using the concept of subscripting variables and using short records most problems seem to be solved. Plot cruisers must record their observations as numbers, coded for items such as a log grade and species.

By imposing two additional constraints, data can be recorded effectively even with a 12-digit display. First, up to 34 variable subscripts had to be memorized. Second, each plot had to be measured the same way. Cruisers adapted readily to memorizing the codes. After observation of several experienced cruisers in the field, we developed a data-entry routine that required minimal adjustment of plot procedure. Basically, cruisers must first record a set of observations on all trees in the prior inventory. Next the same set is recorded for each new tree growing into the sample plot. The balance of observations for each tree is next in sequence.

Most losses in cruiser efficiency stem from the inability to handle more than one tree at a time. Adjacent trees may be tallied simultaneously under the old scheme. Heights are measured a known distance from the tree using instruments that measure angles to various points up the tree. Thus, adjacent trees can be "shot" from the same point. Eliminating this flexibility causes some consternation for the cruisers, but we expect several benefits to accrue. One benefit is removal of the tendency for cruisers recording two trees at one time to reverse their observations. Another is that use of a routine recording sequence facilitates training new cruisers and reduces omissions. Cruisers benefit by having prompt feedback on their errors. In this way, errors can be corrected before they become habitual. We also suspect that data entry is easier and faster with the recorder than the tally sheet.

On the computing side, advantages are concrete and drawbacks slight. Gone are visual editing of tally sheets, keypunching, the sources of error they introduce, and the time required to do them. Replacing these are direct input from the field and good intergrity of data. In their 16,000 character memory, the recorders now in use can hold several plots or five days of plot observations. Storing much larger data sets is possible but the risk of losing data through physical abuse of the recorders must be weighed against the price of a phone call. Recorders can be damaged by droping, immersion in water, or other accidents. In addition, storage for extensive periods defeats the advantage of quick response to field errors. Risk of data loss is minimized by having capable personnel and by having the personnel realize data recorders represent an advantage rather than a burden to them.

Technically, the MSI/77 recorders offer several advantages. The circuitry requires less energy than some others, and data may reside in memory several weeks without danger of data loss. Four regular penlight batteries power the unit with two watch batteries for backup. Not much larger than a hand-held calculator, the unit provides line editing, search, and programmable telecommunications features. An acoustic coupler transforms the data into audible signals and enables telecommunication of the data over public telephones. A receiving device (MODEM) translates this signal back into characters for input into the terminal.

A system of programs to decipher each transmission and merge that information smoothly into the routine data-reduction system has been developed for our desk-top calculator. The entire capturing and merging process can be automated with equipment currently available.

An estimate of the cost of a minimum hardware system using data recorders appears high because of the equipment necessary to capture the data. A single recorder cost about \$1,500 when we began our evaluation in 1978. Now a single comparable unit sells for under \$1,000. Our terminal with tape drives cost about \$4,500. Only a \$500 modem and a telephone are required to complete the hardware for a total cost of about \$6,000. As more recorders are added, the cost per unit in the field is reduced. Ten recorders and one terminal would be roughly \$15,000, or a per-unit cost of \$1,500.

Our past experience with contract keypunching indicates a cost of \$3.28 per plot punched. This does not include our personnel cost for pre-editing and preparing tally sheets for the keypunching services. If our field teams enter just one plot per working day, our cost of \$1,500 per data recorder would be amortized in 1.5 years. If we bought additional units today, the break-even point would be within one year.

Some additional cost is incurred for telephone calls. However, we minimize this cost by communicating at 120 characters per second and by calling during off-peak hours. In less than 10 minutes, a week's plot measurements can be transmitted twice. These two transmissions are captured on separate tape devices for later character-by-character comparison and verification. Errors have been few and easily correctable.

In many instances, cost is not the sole criterion for evaluating a data-capture system. When time is a factor, or if personnel restrictions apply, time saved may outweigh other considerations. Another powerful feature of the data-capture system which we employ is automated error correction. Through software on the desk-top minicomputer, error correction has been 10 times faster. Instead of picking through a box of punched cards, locating the error card, and keypunching and reinserting it, the operator references the record uniquely and the minicomputer locates it. Once the error is corrected, the record is automatically restored in the proper place. With the proliferation of mini-computers, such systems are becoming available to more users at reduced cost.

Our data-capture hardware did not arrive in a turn-key package. Many technical and some human-related problems had to be overcome, and potential users should be aware of possible technical problems. The equipment now used has limitations prescribed by current technology. The light-emitting diode display, for example, is difficult to see in bright light. Other models have liquid crystal display, black on gray background, but these units did not have flexible data communication features suitable for use with our terminal.

Another difficulty was the internal configuration of the receiving terminal. The portable recorders do not use standard protocol in communication; sending instead a continuous flow of data. In simple terms, the units only talk, never listen. At first, some internal switches had to be reset for data reception, but this problem was resolved by fabricating a special cable linking the modem and terminal.

We think the concept is viable. We have 20 units for use by our field crews. In Alabama, all timber related data is being entered in recorders. Each crew transmits information weekly. The data will be edited and a list of errors returned to group leaders each week.

SUMMARY

Data recorders have been successfully applied in forest survey. Transition from tally sheets is relatively easy for trained cruisers but some problems persist in viewing records longer than the display. Telecommunications, data capture, and processing are reliable and efficient. Keypunching costs, time requirements, and associated errors are eliminated. The recorders are light, compact, and can communicate with a variety of computer hardware. Needed are special units that are weatherproof, and that can be programmed to prompt cruisers, and to edit records on the plots. If we can abandon the notion of 8-column cards, and have confidence in other data-storage media, the possibilities for applications challenge the imagination.

RESUMEN

Las registradoras electrónicas de data han sido utilizadas con éxito en actividades de campo para el estudio contínuo de bosques. Un nuevo sistema para vaciar la data minimiza la transición que hace el tasador de la hoja de cotejo a la entrada digital. La telecomunicación, el recogido de data, y los procesos subsiguientes son confiables y eficientes. Se eliminan así los costos de perforación manual, el elemento tiempo, y otros errores asociados. La data que se recobra es sencilla, compacta, y puede utilizarse con diferentes equipos de computación.

Efficient Terminal Transmission of Inventory Data[1]

John W. Moser, Jr. and Terry Throssell[2]

Abstract.--Remote terminals with acoustic couplers have provided the means for inventory data to be transmitted from field locations to central sites for processing. Often, however, communications costs are prohibitive for the creation, editing and submission of an inventory file. The development of data terminals with bubble memory provide greater opportunity, flexibility and efficiency for remote data entry. This paper illustrates the features and use of these new terminals with forest survey and with private landowner inventories.

INTRODUCTION

The advent of acoustic couplers provided the means for data terminals to remotely access central computing facilities via voice-grade telephone lines. Theoretically, this development would enable resource managers to have demand access to computers from most field installations. In 1971, Grosenbaugh suggested that remote access should not be "touted as the solution to most computing problems". Over the past decade and even today, that assessment is essentially correct.

Major obstacles to remote access are the quality and cost of communications lines, the long connect time required while a user inputs and edits data and programs, the slow transmission rates for large quantities of data and risk of lost information in the event of system and/or transmission equipment failures. The recent development of a new memory data terminal may alleviate some of these obstacles and provide more efficient access to computers from field locations. This paper will discuss the features of this new terminal and illustrate its use with small woodland ownership inventories and with forest survey for the Intermountain Forest and Range Experiment Station.

[1]Paper presented at the Arid Land Resources Inventories Workshop, La Paz, Mexico, November 30-December 6, 1980.

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THE MEMORY DATA TERMINAL

Texas Instrument Corporation has developed 2 new memory data terminals. Model 763 is designed for office use and may be used with an optional internal modem. Model 765 is lightweight, highly portable and contains a built-in acoustic coupler. While both models have the same performance characteristics, the Model 765 is most suitable for field use by resource managers and it is the one used for the applications discussed in this paper.

A major feature of these new memory data terminals is an electromagnetic bubble memory. It offers many advantages over the more commonly used storage devices with remote terminals such as paper tapes, tape cassettes and diskettes. The bubble memory has no moving parts, is lightweight, uses less power and has faster access speeds than the other remote storage devices, and is nonvolatile, i.e. retains its stored information when the power is turned off. The standard terminal features 20,000 characters of memory but optionally up to 80,000 characters are available in increments of 20,000 characters.

The terminals generate and accept the American Standard Code for Information Interchange (ASCII) codes that may be transmitted or received from devices such as data terminals, computers, video terminals or data recording devices. Traditionally, terminal configuration for communication with other devices has been controlled by switches on the console. These new terminals may be configured by keyboard entered English commands or they may be programmatically executed. Thus, communications between devices can be accomplished with a minimum of difficulties.

Two microprocessor systems and a read-only-memory support the data terminal's operating

system. The user's interface with the operating system is primarily through use of operator commands. These commands may be subdivided into the following functional categories:

1. File Utilities - The file utility commands permit file creation, deletion, and erasure as well as file protection measures. A command is available to copy the content of a file to the printer or another file. Also, files may be catalogued.

2. Parameter Modification - These commands enable the user to check on the status of the communication and terminal display parameters and to change their values to any of the permissible options.

3. File Editing - The editing commands enable the user to edit data and/or programs by inserting or deleting both characters and lines within a file. The find and index functions assist in the location of character strings and/or lines within the file.

4. Command Execution - Terminal commands may be stored in memory for automatic execution. They may be used to prompt an operator for input or to configure the terminal for various communication requirements.

5. Terminal Diagnostics - The terminal and bubble memory may be self tested to insure that they are operating properly.

Many of the operations that are possible with the memory data terminals have traditionally been accomplished in an interactive, on-line mode which often entailed large long-distance charges. These new lightweight, bubble memory terminals with excellent editing and prompting capabilities can offer the resource manager cost efficient alternatives for off-line file creation and the subsequent transmission of prepared files.

SMALL WOODLAND INVENTORY APPLICATION

Timber Inventory and Management Planning Information System is a program to aid in the management of small woodland ownerships (Moser 1980). The system, developed at Purdue University, summarizes forest inventory data collected with a variety of sampling designs and tallying options, calculates stand value by one of a variety of alternatives, determines harvest through one of several cutting options and grows the residual stand.

The program has features specifically designed for service and consulting foresters, timber buyers and appraisers, or other woodland managers that have need for quick, efficient summaries for small tracts. Ideally, these users would submit input and receive output via a remote terminal with hard copy capabilities. The obstacles to this method of utilization are the costs associated with being remotely connnected to a computer site and the user must have knowledge of telecommunications, terminals and the jargon of the host system.

The offline features of the TI Model 765 bubble memory terminal offer new, cost effective possibilities for creating, editing and remotely submitting TIMPIS data. A specific implementation termed TIMPIS PROMPT has been developed to complement the TIMPIS program. TIMPIS PROMPT is a series of run and prompt files that are stored in the Model 765's bubble memory. The run files consist of terminal configuration commands and commands to activate the stored prompt files. The prompt files display input instructions, control the terminal's record and playback files and format the data entered by the user. TIMPIS PROMPT is used through a set of RUN commands which are defined as follows:

(1) HELP : Presents all TIMPIS PROMPT commands and the command syntax

(2) START: Configures terminal for data acquisition and initializes data files

(3) CDATA: Prompts user for TIMPIS control data

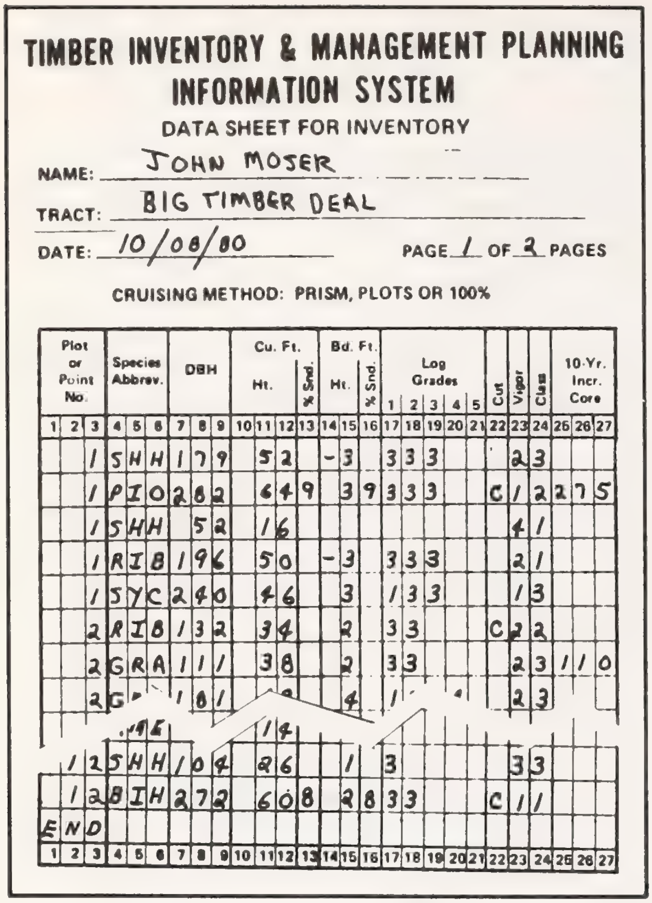
(4) IDATA: Prompts user for inventory data

(5) LIST : Prints files created by CDATA and IDATA

(6) SEND : Configures terminal for file transmission and provides communication instructions

Figure 1 contains data recorded in the field on a tally form designed for use with TIMPIS. Normally, these data would be either keypunched or keyed into an online terminal. However, with TIMPIS PROMPT the data are entered into the terminal offline under the control of the IDATA command. When this command is executed, the column headings on the field tally form are displayed on the printer along with appropriate data field width indicators. The terminal's printhead is automatically positioned for entry of each data item. Figure 2 displays the entry of several lines of data with the IDATA command.

Figure 3 illustrates the prompt for TIMPIS program control information. This prompt is initiated by the CDATA command. It also prompts for ownership and forester information, a heading for all output tables and up to 20 lines of narrative for the printed title page.



TIMBER INVENTORY & MANAGEMENT PLANNING INFORMATION SYSTEM

DATA SHEET FOR INVENTORY

NAME: JOHN MOSER

TRACT: BIG TIMBER DEAL

DATE: 10/08/80 PAGE 1 OF 2 PAGES

CRUISING METHOD: PRISM, PLOTS OR 100%

Plot or Point No. (1–3)	Species Abbrev. (4–6)	DBH (7–9)	Cu. Ft. Ht. (10–12)	Cu. Ft. % Snd. (13)	Bd. Ft. Ht. (14–15)	Bd. Ft. % Snd. (16)	Log Grades 1 2 3 4 5 (17–21)	Cut (22)	Vigor (23)	Class (24)	10-Yr. Incr. Core (25–27)
1	SHH	179	52		-3		333		2	3	
1	PIO	262	64	9	3	9	333	C	1	2	275
1	SHH	52	16						4	1	
1	RIB	196	50		-3		333		2	1	
1	SYC	240	46		3		133		1	3	
2	RIB	132	34		2		33	C	2	2	
2	GRA	111	38		2		33		2	3	110
2	G[illegible]	181	[illegible]		4		1[illegible]		2	3	
[illegible]	[illegible]E		14								
12	SHH	104	26		1		3		3	3	
12	BIH	272	60	8	2	8	33	C	1	1	
END											

Figure 1. -- Illustration of TIMPIS data recording form.

```
> RUN IDATA

ENTER INVENTORY DATA FROM TIMPIS FIELD FORM.

*** PRESS "ENTER" AFTER EACH ENTRY ***
*** PRESS "FCTN ESC" TO TERMINATE  ***

PLOT SPEC. DBH  CF  %  BF  % LOG GDS C V C  10-YR
No.  ABV.       HT  S  HT  S  12345  T I L  CORE
---  ---  --- --- -  --  -  -----  - - -   ---

  1  SHH  179  52     -3      333      2 3
  1  PIO  282  64  9   3  9   333    C 1 2   275
  1  SHH   52  16                      4 1
  1  RIB  196  50     -3      333      2 1
  1  SYC  240  46      3      133      1 3
  2  RIB  132  34      2      33     C 2 2
  2  GRA  111  38      2      33       2 3   110
```

Figure 2. -- Illustration of offline prompting for TIMPIS field data.

As the prompting procedes, each data item is appropriately positioned in the input record and each record is terminated with the automatic device control character DC3 which is necessary to control the playback file on transmission. Also, some of the records are automatically prefixed with special characters to identify the input type for the TIMPIS executive program. The prompting features eliminate program control and data transmission details for the user.

As previously mentioned, the terminal has offline editing capabilities. Figure 4 illustrates the use of the editor. The first 33 in line 5 of the sample data should be just 3. The editor was used to delete the first 3, insert a blank

```
           * * * *   PROGRAM  CONTROL  INFORMATION   * * * *

 JOB    TALLY   NO. PLOTS  SIZE OR   EXPAND   TERMINAL   - SUMMARY GROUPS -
 TYPE   SCHEME  OR POINTS  FACTOR    OPTION   /PRINTER   PRES HARV CUT PRED
  -       -       ----      ----       -         -        -    -    -    -
  1       3        12       10.0       A         T        X    X    X    X

-- SPECIES SUM --    -TREE CLASS SUM--    DIA SPE TCL STA    GROWTH PERIODS
NT BA CF BF $V GR    NT BA CF BF $V GR    SUM SUM SUM SUM    LENGHT    NO.
 -  -  -  -  -  -     -  -  -  -  -  -     -   -   -   -       --       --
 Y  Y  Y  Y  Y  Y                                      S       10        1

  CUT     CUT    RESID   CUT CTL   ECON   INTER   CONV  GRD  LOG  LOG   HT  LOG
 OPTION   FREE    BA     FACTOR    ANAL   RATE    COST  OPT  GRD  RULE  OPT LEN
   --      -     -----   ------     -     -----    -     -    -    -     -   --
   1             65.0               0              0     0    1    1     0   16
```

Figure 3. -- Illustration of offline prompting for TIMPIS program control data.

```
EDIT IDAT

 1SHH179 52 -3 333    23
 1PI0282 649 39333   C12275
 1SHH 52 16           41
 1RIB196 50 -3 333    21
 1SYC240 46 33 133    13

 1SYC240 46 3 133    13


             3 133    13
 0
 1SYC240 46  3 133    13
DONE
```

Figure 4. -- Illustration of the TI 765's editing features.

character in its place, and to print the corrected line. The D_3 at the end of each line in Figure 4 is the automatic device control character that terminates each input record created on the terminal.

After all data are entered into the terminal and edited, they are ready to be transmitted to a host system for processing. This operation will be different for most users since the telecommunications protocol varies between computer systems. The SEND command for TIMPIS PROMPT was developed for transmitting data to the Purdue University Computer Center. It is illustrative of the transmission possibilities that are feasible with memory data terminals.

Figure 5 contains the user instructions given by executing the TIMPIS PROMPT SEND command. In this application the terminal parameters are appropriately configured, the inventory data file is designated as the playback file and rewound,

```
RUN SEND


***********
 THE TERMINAL HAS BEEN CONFIGURED FOR
 TRANSMISSION TO PROCSY.  FOLLOW THE
 STEPS BELOW:

   1) CALL 494-6411; WHEN SIGNAL IS
      RECEVIED PLACE RECEIVER IN THE
      ACOUSTIC COUPLER.
   2) TYPE "CTRL B" AND LOGON TO PROCSY.
   3) WHEN +++ APPEARS,  ENTER
           "PFILES(GET,TRUN,ID=xxx)".
   4) WHEN +++ APPEARS AGAIN,  ENTER "TRUN"
   5) FOLLOW INSTRUCTIONS PRINTED ON
      TERMINAL.
```

Figure 5. Instructions from the TIMPIS PROMPT SEND command.

the user is instructed to log-on to Purdue's computer and to obtain and execute a macro file stored on the host system. The macro is a program written in a language of predefined utility functions that will create a local file and load it with data from the terminal's playback file, create a jobcard with the logged-on user account and submit the data to TIMPIS for processing. After the transmitted data is submitted to the batch system, the user is instructed to log-off and called back later to collect the output.

TIMPIS PROMPT effectively creates the control and data files for TIMPIS. The prompting minimizes user difficulty and guides the user through file creation. Connect time and line charges are greatly reduced as 2 short telephone calls replace the long call necessary for file creation and editing. Loss of data from transmission difficulties is minimized since a copy is stored in the terminal. The user must learn to operate the terminal's editor. It is flexible but requires practice for the user to become proficient. The use of delimiters in creating the inventory data file may improve the present version of TIMPIS PROMPT. This would add flexibility in tabbing for the input data but would require a new program on the host system to decode and format the data as TIMPIS input.

In summary, the new bubble memory terminal appears to offer many potential applications for the remote transmission of data and programs. This is illustrated for the small woodland manager.

FOREST SURVEY ILLUSTRATION

The USDA Forest Service, Intermountain Station, Renewable Resources Evaluation Work Unit, located in Ogden, Utah, experimented with the TI 765 portable memory data terminal[3] on its 1979 inventory of state and private forest lands in Grand County, Colorado.

Some systems design work had to be done before the new terminal could be used. The old system was geared more to keypunched data and involved a central shop of many people, each doing a small portion of the job. Data were logged in by one person, keypunched and verified by another, loaded on the computer for sorting and editing by a third, corrected by a fourth, and so on. A decision was made to modify the system so that one person could do all portions of the job from a terminal. To enable one person to handle all the tasks without burdensome paperwork the new system would have to automatically keep track of control information which had previously been maintained by hand.

---

[3]The use and description of the TI 765 terminal by the U.S. Forest Service does not constitute endorsement of this product.

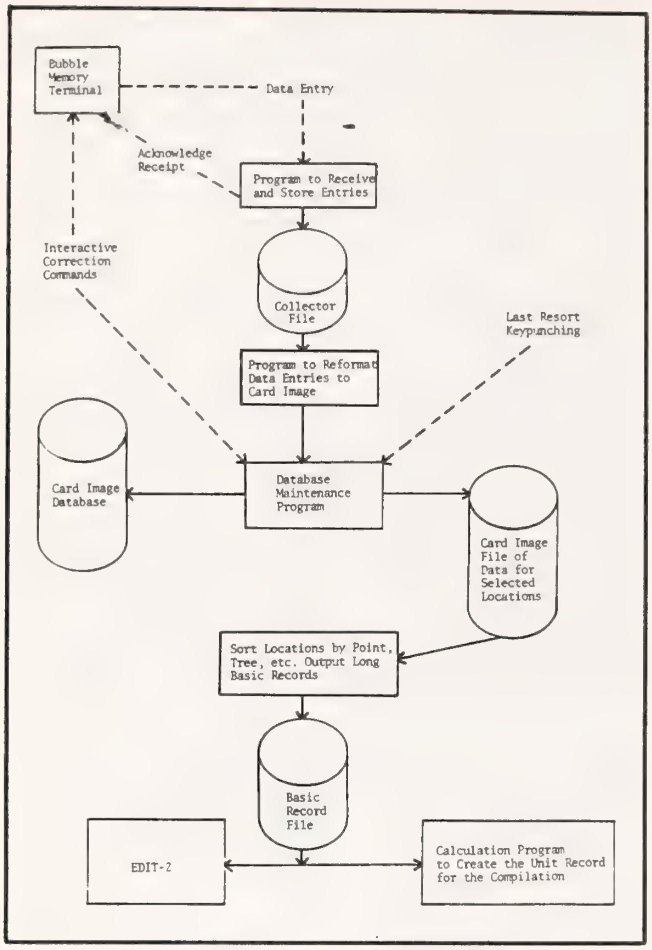


Figure 6. -- Flowchart of the Intermountain Forest and Range Experiment Station's forest survey system.

Figure 6 depicts an overview of the modified system. It is the old system except that a loop has been added to accommodate input from the terminal. This loop contains programs to receive and store the terminal entries and then reformat them to card image to be compatible with the keypunched input. All input data were stored in a generalized card image data base which could be updated either interactively from the terminal or in a batch mode with cards. Data selected for output from the data base were sorted and further manipulated into a standard format which was compatible with an EDIT-2 program to check the data for logical errors and a calculation program to create the unit record file for the compilation.

To discuss the operation of the terminal and the system on the Grand County, Colorado inventory, consider data entry. It can be divided into two phases. The first step, data preparation, takes place offline; that is, with the terminal operating as a stand alone device. The second step, data transmission, takes place online, with the terminal communicating with the host computer.

Data preparation began with grouping the source documents into 'lots' where one 'lot' was as much data as would fit into the terminal's bubble memory at one time. Next the data for the 'lot' were typed into a file in the terminal's bubble memory. The file was printed and the listing compared against the source documents. Any discrepancies were corrected using the terminal's built-in editor. These offline operations were easy to learn. Inexperienced operators could master the tasks.

Data transmission proved a more difficult task, even with the help of a terminal run file to set the communication parameters and assist the operator. Dialing the host computer, signing on and then giving a few commands to transmit the data seemed a simple procedure on paper, but in practice operators with little computer experience had trouble. Suffice it to say that many unexpected events can happen when online and that there is no substitute for prior computer experience.

Before describing further operations it will be useful to introduce a bookkeeping feature of the data base. Data were stored in the data base by 'lot' number. Keeping track of which 'lots' had been corrected and which needed to be checked for errors was a burdensome task when done by hand. To help one person operate the system, the data base automatically maintained a table of status information for each 'lot'. The status flag for each 'lot' could take on the values 0 or 1. A 0 value meant that the 'lot' had either not been entered or that it had recently been output to the program to check the data for logical errors. A value of 1 meant that the 'lot' had just been entered or that it had just been corrected. In either case the 1 value signified that the 'lot' should be output to the program to check the data for logical errors.

The program to check the data for logical errors was part of a procedure which worked with the data base table of 'lot' status information. The procedure output data for every 'lot' whose status flag value was 1 and then reset the value of the status flag to 0. In this manner, only those 'lots' that needed to be checked for errors were examined. Also, the system did the work automatically; the operator did not have to modify the computer job control language.

In Grand County, Colorado, the error listing was routed to a convenient high speed printer. This listing could have been routed back to the terminal instead. On the terminal, the listing could have been printed directly or it could have been recorded into a file in the bubble memory for printing multiple offline copies.

The correction process also worked with the data base table of 'lot' status information. Records on the error listing were identified by

their 'lot' number and within 'lot' sequence number. Commands to correct a record involved identifying the lot, sequence number, and field name, for example,

```
**LOT 18

*SEQ 3

AZIMUTH=58

TREE NUMBER=3

*SEQ 4

TREE NUMBER=4

**EXIT
```

Each time a 'lot' was corrected its status flag was set to 1. This way the corrected 'lot' would be double checked by the error detection program.

The correction commands for the Grand County, Colorado, inventory were punched on cards and submitted as a batch job. The terminal could have been used to enter the commands interactively if more demand lines had been available. The commands could even have been entered offline into a file in the terminal's bubble memory and then transmitted to the computer.

To conclude, use of the bubble memory terminal on the Grand County, Colorado, inventory was a successful, if limited, experiment. The data were entered and edited as fast and possibly faster than it would have been under the old central office routine. One person could do all portions of the job from the terminal, and some portions of the job could be done entirely offline resulting in a considerable dollar savings.

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RESUMEN

Los terminales remotos con conectores acústicos han hecho posible la transmisión de datos a ser procesados desde su localización en el campo, a los locales centrales. Sin embargo, frecuentemente los costos de comunicación son prohibitivos para la producción, redacción y rendición de un archivo para inventario. El desarrollo de terminales con memoria de burbuja para datos provee mejor oportunidad, flexibilidad y eficiencia para la entrada remota de datos. Este trabajo ilustra las características y el uso de estos nuevos terminales en el estudio de bosques y en los inventarios de hacendados privados.

Storage, Manipulation, and Display of Geographic Multi-Resource Data for La Michilia Biosphere Reserve in Mexico[1]

William O. Rasmussen, Peter F. Ffolliott, and Gonzalo Halffter[2]

Abstract.--To predict land management outcomes, a multitopic geographic data management system in which location specific data (collected on La Michilia Biosphere Reserve in Mexico) can be stored, manipulated, and displayed by computer was developed. To date, descriptions of vegetation, topography, climate, geology, soils, and land capability have been included and can be displayed as generated maps, contour plots, or three-dimensional surfaces. An example of the system's use is also discussed.

INTRODUCTION

The purpose of UNESCO's Man and the Biosphere (MAB) Program is to develop a basis, within the natural and social sciences, for rational use and conservation of the biosphere (that portion of the earth's crust and lower atmosphere which contains life) and for the improvement of the relationship between man and the environment. In keeping with the MAB philosophy, a binational Mexico-USA program of research and education, entitled COMPARATIVE STUDIES OF DRY FORESTS OF WESTERN NORTH AMERICA, has been established. Within this program, joint efforts culminating in wiser use and conservation of natural resources are being coordinated for the benefit of people in both nations.

As part of the binational Mexico-USA program of research and education, multiresource inventory methods are being developed to provide baseline information for multiple use management of natural resources on La Michilia Biosphere Reserve in the State of Durango, Mexico. Included as a component of these inventory methods is a multitopic geographic data management system in which location-specific data can be stored, manipulated, and displayed for land management planning evaluative activities.

In this paper, the multitopic geographic data management system developed for La Michilia will be outlined, and then its use illustrated through a specific application. It should be noted that, while this system meets particular data interrogative needs on La Michilia, by design, its framework can readily be structured for use elsewhere.

LA MICHILIA BIOSPHERE RESERVE

La Michilia is a large plateau 75 kilometers southeast of the City of Durango. Elevations range from 2,250 to 2,600 meters, with mountains rising on two sides to 2,850 meters. The area includes 42,000 hectares, 7,000 hectares of which are an integral preserve, with the remaining 35,000 hectares a buffer area. On the buffer area, livestock grazing and controlled harvesting of timber is permitted, while complete legal protection of flora and fauna exists within the preserve.

Pine-oak forests constitute a major vegetative type in the dry forests of La Michilia, with juniper-oak woodlands and grasslands comprising other vegetative types found on differing topographic areas. Soils range from acidic and igneous rock to clay and sand. Several creeks and temporary lakes constitute the water sources. Precipitation averages 500 to 700 millimeters each year, and temperatures fluctuate from 12°C to 28°C.

To date, research efforts on La Michilia Biosphere Reserve have centered around studies of flora and fauna, while other studies have been conducted on industrial use of regional products of agriculture, new crops to utilize the labor force, and investigations of food sources (Halffter 1978).

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[1] Paper presented at an International Workshop on Arid Land Resource Inventories: Developing Cost-Efficient Methods, La Paz, Mexico, November 30-December 6, 1980.

[2] Rasmussen is assistant research professor and Ffolliott is professor, School of Renewable Natural Resources, University of Arizona, Tucson, Arizona, USA. Halffter is Director, Institute of Ecology, Mexico City, D.F., Mexico.

OUTLINE OF THE GEOGRAPHIC DATA MANAGEMENT SYSTEM

In general, source data contained in the multitopic geographic data management system for La Michilia have been obtained from base resource maps of the area, aerial photographs, and supplementary field measurements. Most of these data topics have been converted to a digital format for storage and subsequent manipulation in a computer. Associated with these data topics are programs that allow the source data to be displayed as generated maps, contour plots, and as three-dimensional surfaces. Various types of data analysis can be performed, and several computer simulation models have been coupled with the source data to predict land management outcomes.

Herein, the development of the multitopic geographic data management system with respect to source data obtained from available base resource maps of La Michilia will be outlined.

Base Resource Maps

To date, six base resource maps have been included in the geographic data management system for La Michilia Biosphere Reserve. These maps are: vegetative, topographic, climatic, geologic, edaphic, and land capability. The flexibility of the system allows for the inclusion of additional base resource maps and other data topics generated from aerial photographs and supplementary field measurements, as required.

Data Input and Storage

To develop the multitopic geographic data management system for La Michilia, the six base resource maps were digitized on an electronic digitizer. In essence, the digitizing process involved transformation of the base resource maps into a digital format that can be stored, manipulated, and displayed utilizing a computer and its peripheral devices. The base resource maps generally fell into one of the following two types, with a different digitizing approach employed for each type: maps with information that is consistent throughout bounded subareas, typified by the vegetative map; and maps with information that varies throughout a subarea, as exemplified by elevation on the topographic map.

Where information is consistent throughout a subarea, as on the vegetative map, digitization entailed placing the map on a digitizing table and determining groups of point coordinates which delineate the boundaries of all subareas on the map. The boundary of each subarea was depicted by a series of point coordinates that defined a polygon. A numeric code was then associated with the vegetative type within the polygon. Data representing all of these subareas were input to a computer to grid the subareas into a number of rectangular cells. Also, the computer program assigned a value to each rectangular cell to index the vegetative type having the predominate aerial coverage within the cells. In this fashion, a numeric data array of values was generated to represent a paper analog map.

For digitization of maps with information that varies throughout a subarea, a slightly different approach was used. In the case of the topographic map, for example, it was first placed on the digitizing table. Then, for each of selected, irregularly spaced points of the map, the data triplet of elevation and map corrdinates of the point were determined. The entire group of data triplets were later entered into a computer program which interpolates from the selected, irregularly spaced points to output elevational values for the centers of cells which collectively defined the map. In such a manner, a numeric data array was produced to represent the topographic map.

All of the base resource maps included in the geographic data management system for La Michilia were digitized using one of the above approaches. The resultant numeric data arrays, representing the base resource maps, were stored in a computer so that, for each cell on the area, resource attributes describing it were readily available for manipulation and display.

The assemblage of data values for all of the resource topics considered is, by definition, the framework of the geographic data management system for La Michilia Biosphere Reserve. Associated with this framework are several computer programs that allow for introduction of additional resource topics into the existing data base; manipulation of data contained in the base; and display of the products of manipulation or of any topics within the data base.

Data Output and Display

The numeric data arrays representing the various resource topics in the geographic data management system for La Michilia can be displayed using several graphic formats. As an example, the array derived from the edaphic map is displayed in figure 1 to illustrate soil types. In figure 1, each soil type has been assigned a numeric code value and is represented on the map as a region with a specific form of symbolism or shading. The map legend shows the correspondence of numeric soil code and symbolism or shading used to display it. The legend also gives the area in each of the soil types as well as the percent of the overall map in each soil type.

Another format of displaying the numeric data arrays is through a three-dimensional perspective plot. For purposes of illustration, the elevational data array generated from the topographic map is presented by this format in figure 2.

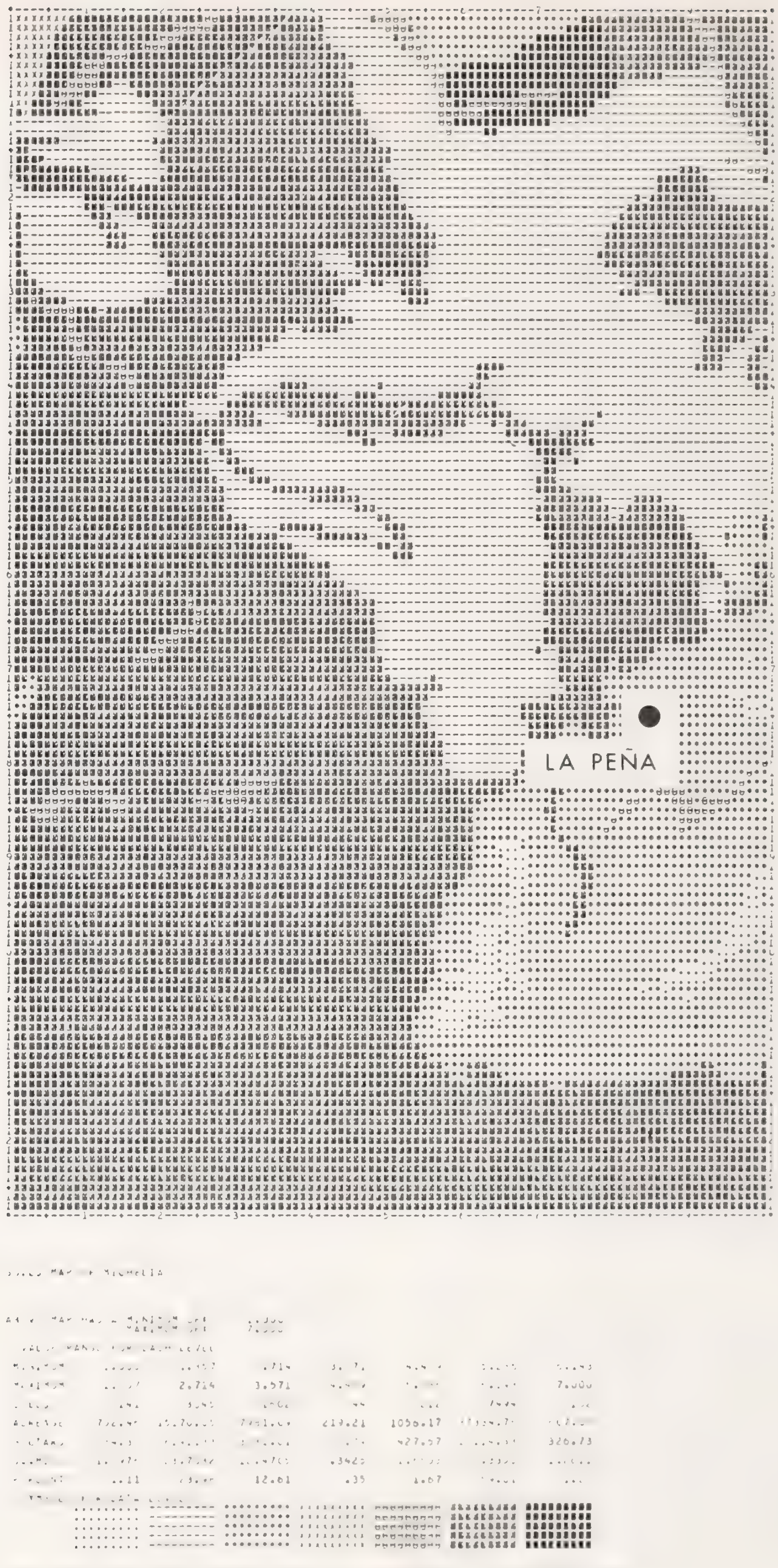


Figure 1.--Example of method of displaying various soil types through symbolism or shading.

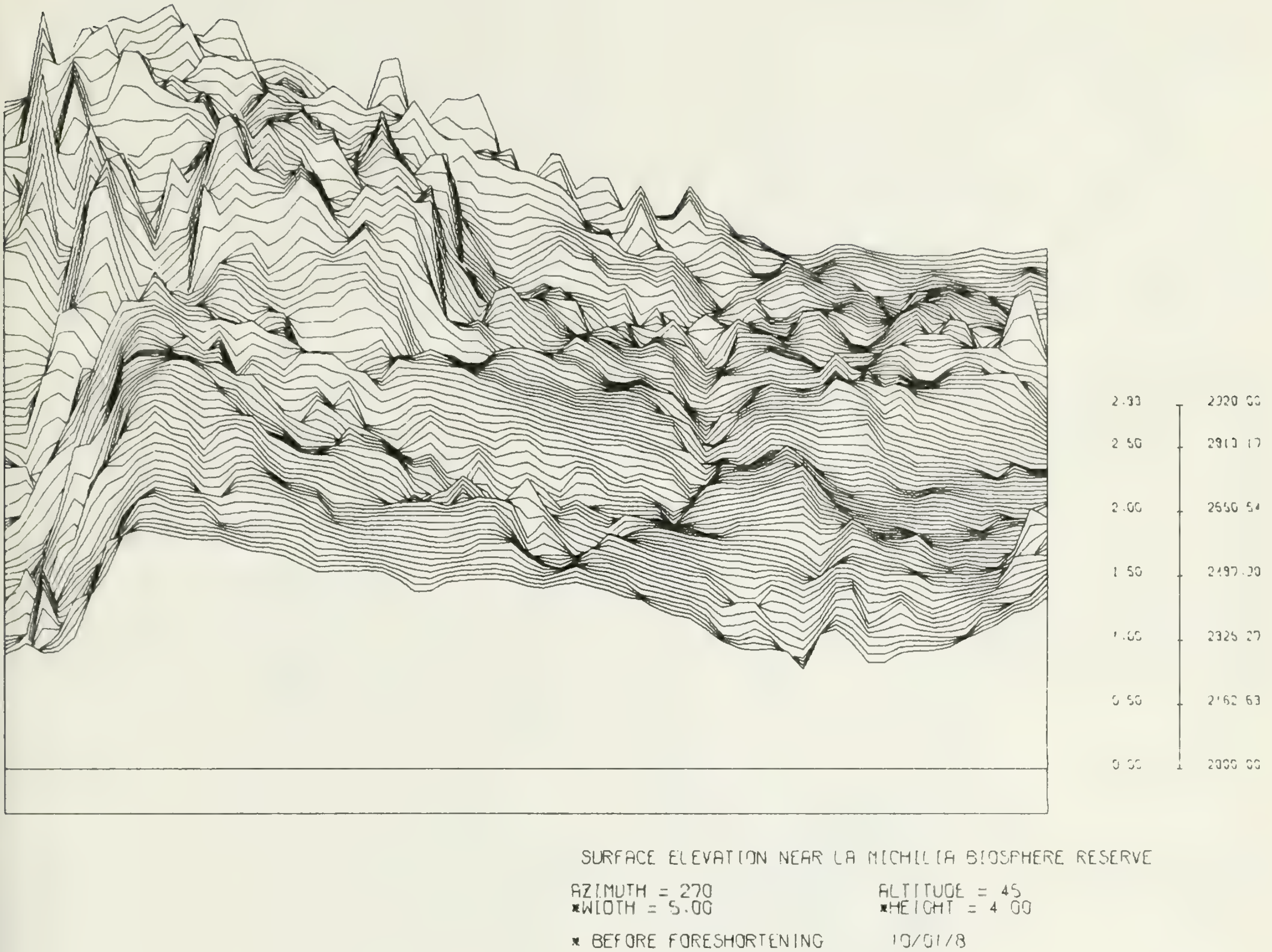


Figure 2.--Example of method of displaying various elevations through a three-dimensional perspective plot.

ILLUSTRATION OF USE

To illustrate the use of the multitopic geographic data management system developed for La Michilia, the system has been interrogated to spatially characterize preferred white-tailed deer habitat on the Biosphere Reserve. In specific, through use of the system, it has been possible to define and then study the relative juxtaposition of preferred areas. Such knowledge helps to form a better understanding of habitat requirements for white-tailed deer in Mexico.

Descriptors of Interrogation

From exploratory investigations of habitat use through analysis of fecal droppings and other field work, general information on sites preferred by white-tailed deer as habitat has been obtained by wildlife biologists on La Michilia. It has been found, for example, that areas of high use correspond to open pine-oak forests, generally on plateaus greater than 2,600 meters in elevation. Feeding areas for white-tailed deer are often located on slopes not exceeding 10 percent. It is common to find more signs of white-tailed deer activities (feeding, bedding, etc.) on lee western slopes than on exposed eastern slopes. Also, areas of high use on La Michilia for the most part are characterized by deep soils with high organic content.

Computation and Display of Preferred Habitat

By converting the above descriptors of preferred white-tailed deer habitat to numeric con-

straints, a map of the amount and the spatial distribution of preferred habitat on La Michilia Biosphere Reserve was produced. To obtain this map, the numeric constraints on the various resource topics were applied to each cell in the data base. If a cell had the appropriate resource values, it was determined to be a preferred habitat, and a value of 2.0 was placed at that cell location on a numeric data array representing preferred habitat. If a cell failed to meet the requirements for preferred habitat, a value of 1.0 was given to that cell in the data array. For this illustration, the numeric data array for preferred white-tailed deer habitat is presented in figure 3 as a shaded, grey printer map. The map legend shows approximately 900 hectares of preferred habitat exist on La Michilia at the present time.

It should be noted that a multitopic geographic data management system of the kind developed for La Michilia facilitates determination of the effects of land management activities on the amount and the spatial distribution of preferred white-tailed deer habitat (or similar resource parameters), if the descriptors of preferred habitat are modified accordingly. For example, conversion of pine-oak forests to grasslands can be expressed through a modified descriptor for vegetation, and the effects on the amount and the spatial distribution of preferred habitats can be easily determined. Similar computations manually would be tedious and involved.

FUTURE DIRECTIONS

As other data topics become available, they can be incorporated into the multitopic geographic data management system for La Michilia. To this end, it is anticipated that source data and supporting information necessary to define areas of prime cattle development will soon become available and included in the multitopic geographic data management system. Through interrogations of the multitopic geographic data management system, areas of potential competition between white-tailed deer and cattle can then be ascertained. Subsequently, if areas of potential competition so warrant, it is conceivable that appropriate land management practices can be designed to insure wiser use of white-tailed deer and cattle on La Michilia

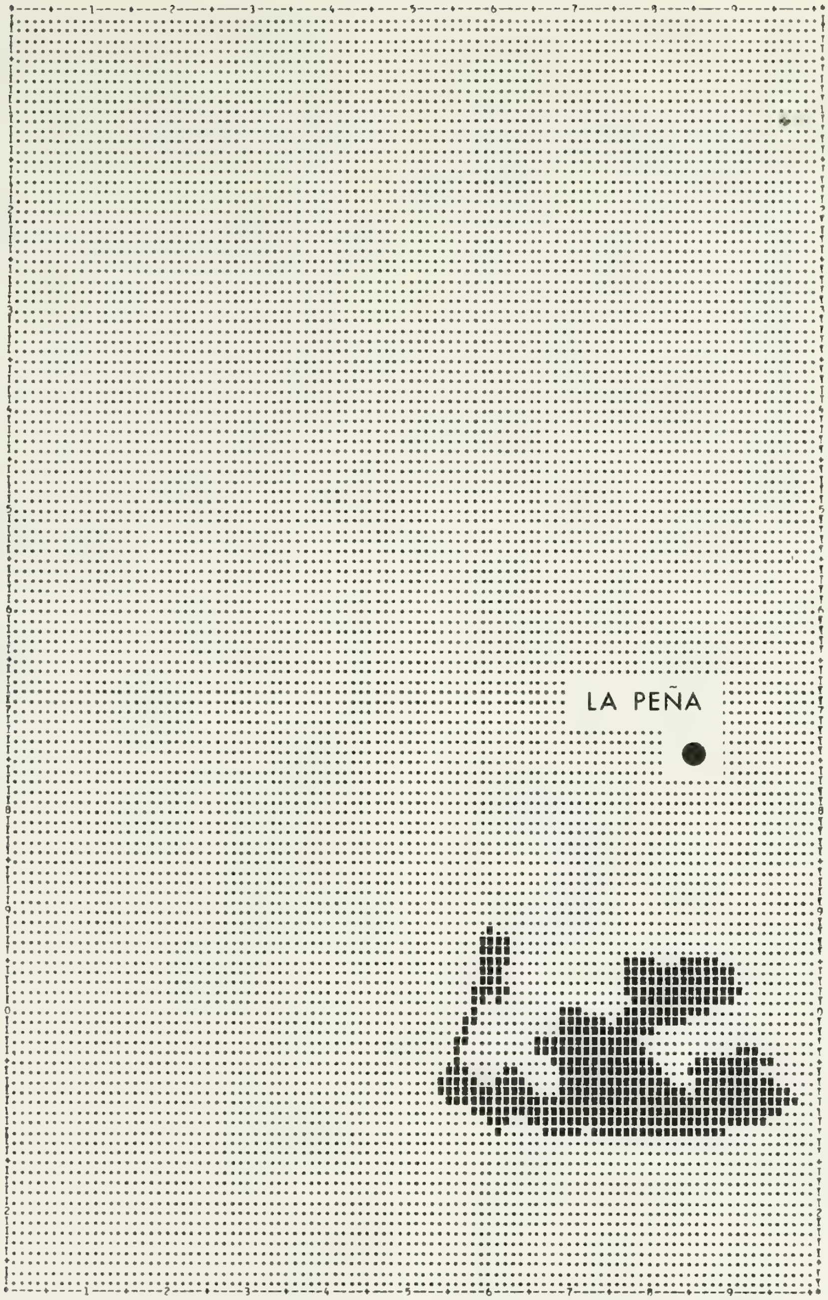
In parallel with the multitopic geographic data management system, continuing efforts are underway to produce simulation models and other analytical tools to operate in conjunction with the multiresource inventory methods being developed on La Michilia Biosphere Reserve for land management planning and evaluative activities

LITERATURE CITED

Halffter, Gonzalo. 1978. Reservas de la biosfera en el estado de Durango. Instituto de Ecolgia, Publicacion 4, 198 p.

RESUMEN

Para predecir los resultados del manejo de tierras se ha desarrollado un sistema multitópico para manejo de data geográfica en el cual los datos específicos de localización (recolectados en la Reserva Biósfera La Michilia en México) pueden ser almacenados, manipulados y desplegados por medio de computadoras. Hasta ahora se han incluído descripciones de la vegetación, topografía, el clima, la geología, los suelos y la capacidad de la tierra, y éstos pueden ser desplegados en forma de mapas reducidos, sitios de contorno o superficies tridimensionales. Se discute además un ejemplo del uso de este sistema.



PREFERRED DEER HABITAT

ABOVE MAP HAS A MINIMUM OF: 1.000
MAXIMUM OF: 2.000

VALUE RANGE FOR EACH LEVEL

MINIMUM	1.000	1.100	1.200	1.300	1.400	1.500	1.600	1.700	1.800	1.900
MAXIMUM	1.100	1.200	1.300	1.400	1.500	1.600	1.700	1.800	1.900	2.000
CELLS	12267	0	0	0	0	0	0	0	0	433
ACREAGE	61113.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2157.19
HECTARS	24740.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	873.30
SQ.MILES	95.4903	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	3.3706
PERCENT	96.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.41
SYMBOLS FOR DATA LEVELS	....	---------	=========	+++++++++	*********	XXXXXXXX	000000000	888888888	████████	████████

TOTAL AREAS: 12700. CELLS 63270.81 ACRES 25614.09 HECTARES 98.86 SQUARE MILES

Figure 3.--Numeric data array for preferred white-tailed deer habitat is presented as a shaded grey printer map.

New Mexico Systemic Resources Analysis Programs[1]

Bill Isaacs
Jim King

The New Mexico Department of Natural Resources has initiated development of a comprehensive natural resources planning system. This system is designed to provide information in a form so that decision makers will have the necessary data and analytical systems to make timely, verifiable decisions as natural resource issues arise.

The New Mexico Natural Resources Department is charged with the management responsibility for the State's renewable natural resources, including wildlife (plant and animal), water (surface and ground), soils, and forests. Presently and for the past several years New Mexico has been experiencing a rapid rate of growth in both population and energy development. This growth has placed, and is expected to place even greater, unprecedented demands upon our natural resource base.

Over the years, the State has almost always found itself in a reactive posture relative to natural resource issues. There was very little opportunity for the state to comprehensively and objectively identify and address issues in a proactive rather than reactive posture. Recognizing this, and realizing that, due to the rates of growth for comsumptive use of our natural resources, the State could ill afford to remain in a reactive position, the Natural Resources Department Secretary, Mr. Bill Huey, ordered the development of a Comprehensive Natural Resources Planning System capable of identifying and addressing critical issues before they were beyond our effective control.

Given this direction, Mr. Jim King, Deputy Secretary for the Natural Resources Department, conceived and proposed the development of the New Mexico Systemic Resource Analysis Program (SRAP). SRAP received its impetus from the earlier work of Mr. Bill Isaacs, as Director of the New Mexico Natural Heritage Program. With the support of Bruce King, Governor of New Mexico, funding for SRAP development was obtained from the New Mexico State Legislature and the United States Secretary of the Interior. SRAP is currently in the development phase and is expected to be in full operation by the spring of 1981.

[1] Paper presented at the Arid Land Resource Inventories workshop, Nov. 30-Dec. 6, 1980, La Paz, Mexico.

The basic structure of SRAP consists of three interrelated components.

I. The Resource Analysis and Issue Identification System; designed to elucidate and develop priorities on state natural resources issues. This system relies heavily on the next SRAP component for managing the large and diverse amounts of data necessary to the analytical processes.

II. The Heritage Information Statistical System (HISS); a computer system of interralated data bases. HISS was built upon, and has one of it's modules the data management capabilities necessary for the next component of SRAP.

III. The New Mexico State Natural Heritage Program; designed along the lines of all the Nature Conservancy State Programs.

I. The Resource Analysis and Issue Identification System

This system has as its principle objective to comprehensively and objectively identify current and projected natural resource issues and to develop policy recommendation designed to address the identified issues. The system is manual presently, but plans exist to automate the system using modeling techniques and sophisticated computer data handling capabilities.

Specifically the system is structured in four phases as follows:

Phase I: Issue Identification - is accomplished via a structured supply and demand analysis of individual natural resource elements. The initial step in the analysis is to overlay mapped data on element supply and demand with mapped data on population growth and energy development. There are four scenarios which are chosen based on the availability of present and projected supply and demand data. This first step identifies areas of potential resource conflict. Once areas are

identified for an element, specific, highly structured, empirical analysis occurs which yields the specific resource issues by area. It should be pointed out that Phase I is not an extensive analysis of issues but merely the identification of issues.

Phase II: Issue Priorities - when Phase I is complete for all elements we begin a political process culminating in the identification of priority issues by the Secretary of Natural Resources and the Governor.

Phase III: Issue Analysis - once priority issues have been chosen an extensive analysis is performed to answer the following basic questions:

1. Where, specifically is the conflict?
2. Why, specifically is there a conflict in each area?
3. What resources are required to resolve the conflict?
4. What are the alternative solutions to the problems?

The analysis involved in addressing these questions is highly structured and contains tests for completeness and objectivity.

Phase IV: Policy Decision - we now enter a second political process where in identified alternatives are reviewed by members of the Executive Cabinet and other individuals designated by the Governor. After consulting with these people the Governor will then issue policy direction which could include; an Executive Order, proposed legislation, adoption of rules or regulations, and other actions within the power of the Executive.

II. The Heritage Information Statistical System

The Heritage Information and Statistical System (HISS) was developed by the Natural Resources Department as a data management tool to assist managers in making decisions regarding the use and allocation of natural resources. It is also designed to be the principle data management tool for the Resource Analysis and Issue Identification System. An additional purpose of the system is to provide researchers with a first look at potential sites prior to going into the field. This reduces the time required for exhaustive literature searches. In essence, HISS is intended to serve as a single depository for most categories of natural resources data such as plants and animal species, geology, archaeology, hydrology, etc. Management of the data categories is achieved by a set of computer programs which controls the input, update, searching and printing of the data base. Much of the power of the management programs is derived from their ability to perform correlations and investigate interralationships and intrarelationships among the various data bases, as well as graphically display the output in a singular or multiple overlay fashion. Some of the potential users of HISS are federal and state agencies, county and local governments, universities, as well as private companies and non-profit organizations.

System Design - The overall design of HISS is to allow maximum flexibility and the option of alterations in data content, manipulation and output representation. To accommodate this, HISS was built as several interacting subsystems, each of which fulfills a major requirement of the overall system. Every subsystem also has the ability to operate in a stand-alone environment if required. To accommodate the primary purposes of HISS, the following sub-systems have been included. First, Natural Resources Information System (NRIS). This is the central subsystem in HISS and it serves two functions:

A. It controls the interfacing between each and every subsystem.

B. It handles all of the site specific data belonging to each of the data categories.

Second is the Geographic Information System (GIS). This is one of the three subsystems obtained from outside of the Natural Resources Department. The particular GIS selected was developed by NASA for use with their Land Satellite Program. A GIS is built to input, store, manipulate and graphically display data pertaining to features which have definable boundaries. Examples are soil types, land ownership and energy and transporation corridors.

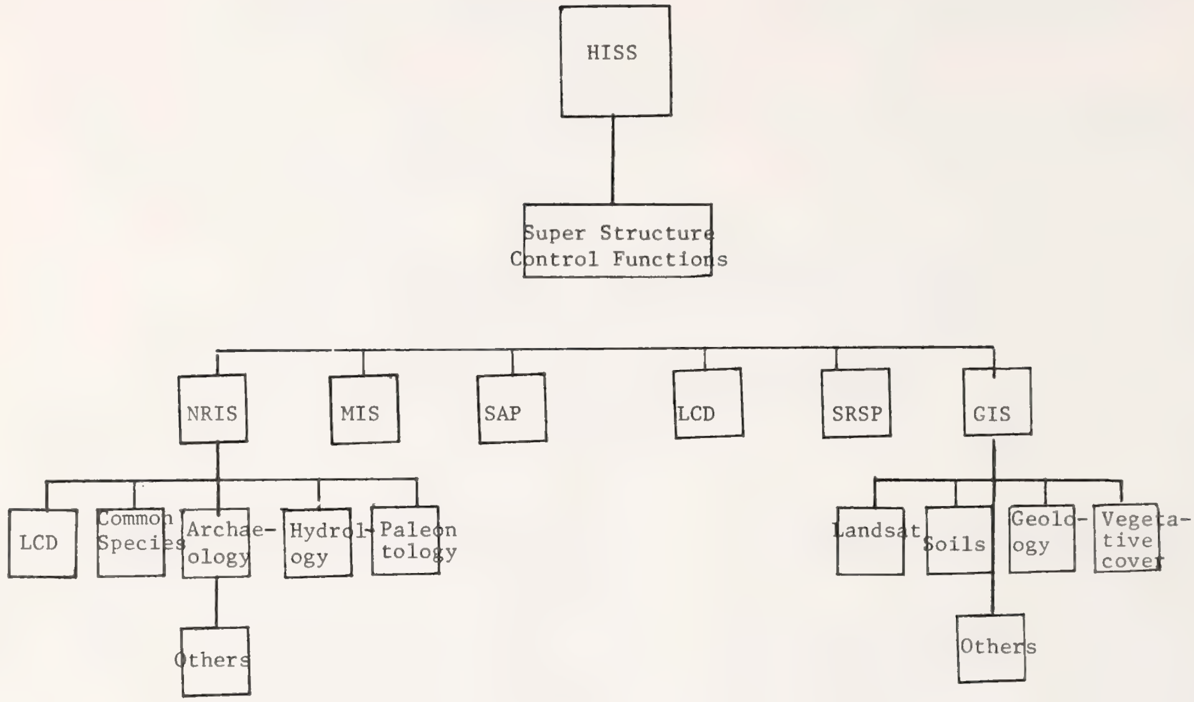
The third subsystem is the Least Common Denominator (LCD) which was supplied by the Nature Conservancy and will be described in the next section of this report.

The fourth subsystem comprises the Scientific Reference Search Program (SRSP). This is a complete and highly flexible bibliographical package.

A fifth subsystem is the Map Information System (MIS) which serves as a bibliographical or catalog system for maps. Map titles may be obtained by subject, area represented and/or author.

The sixth and last subsystem is the Statistical Analysis Package (SAP). This is really a large collection of simple to sophisticated statistical programs. Examples are simple correlations, pattern recognitions and various regression techniques.

Each of the subsystems developed within the Natural Resources Department is modular in design. This permits easy and rapid program modification when changes are required, as well as reducing the time involved in systems testing, and lowers total cost. It should be stressed that the type of data handled by NRIS is complementary to that handled by a geographic information system. What follows is a schematic of the HISS System. It does not represent all of the specific data categories or characteristics of HISS but is generally representative.



Since NRIS is the primary data handling subsystem, some additional explanations are required. Each data category, such as archaeological, plus a small set of specialized programs constitutes a data module. It should be kept in mind that a number of data bases will have two components, a site specific one and an area based one. Examples are vegetative cover, geology, archaeology, etc. The utilization of site specific data serves to act as a check on area based information mapping of site data may show certain area based boundaries are incorrect and that adjustments be required. Those state agencies with statutory authority for a particular data module may be responsible for selection, input and updating that data base. This permits the state's expertise in the various data categories to be realized within the data base, giving it a certain level of accuracy and credibility.

Keeping with the concept of flexibility, the data content for each of the data modules may vary considerably according to user requirements. The only information required in every case is the identity and location by township/range/section of each data entry; otherwise the content and length of each data field may vary as required. This type of data structure permits the system to accomodate nearly any kind and form of existing data, as well as expansion of that data at any future time.

Since HISS may be used by a wide variety of organizations and individuals, there are multiple access control mechanisms to prevent unauthorized access to certain critical data modules (such as endangered species and archaeology). Some of these control mechanisms will also limit certain users as to which subsystems they may use and also exactly what they may do within each subsystem. Depending upon the severity of an unauthorized access attempt, that user may be prohibited from any future use of HISS.

Those organizations which are heavy users of HISS will have the necessary computer terminals installed within their own offices. Less frequent users will request the desired information through the Natural Resources Department. This permits still another access control mechanism.

Those subsystems of HISS which were developed by the Natural Resources Department are written in APL-PLUS. This allows for rapid program development, testing and implementation. In addition, the system is fully interactive, thus the user merely responds to a sequence of promptings to use the system. A user has no need to know or understand a computer language or how a computer operates.

The retrieval system has a bi-level search structure. The primary search operates only on element identity and/or township, range and section. The secondary search may perform a large combination of logical operations on any data field specified. This may be repeated sequentially to further reduce the data. The advantages of this search structure are:

1. often the primary search is all that a user will require;

2. the primary search produces a large data reduction rapidly and at minimum cost;
3. complicated search and data reductions are performed on only the data selected by the primary search; and
4. if the result of the secondary search is undesirable, a backup may be made to the result of the primary search or that of the last secondary search.

The actual data content of the output listing may be limited to just those fields which the user requires or is allowed to access. In this way locational information may be suppressed on critical occurrences. Further, the data elements may be sequenced in an ascending or descending order of any data field, or a hierarchy of data fields. The output may be displayed on either a CRT or hard copy terminal, or routed to a high speed printer.

Upon user request, subsystem interfaces can be established between the Natural Resources Information System, the Map Information System, the Scientific Reference Search Program and/or the Geographic Information System. This would, for instance, permit the inclusion of all map titles that pertain to the study area, all bibliographical information relating to the study area, or other supplied key words.

Additional features under consideration for development include automatic conversion of synonyms for scientific names. This will prevent the same species from being listed under a variety of names or misspellings. Another additional feature would be the conversion of scientific to common names at the time of printing. A further example of auxiliary information contained within a data base is the classification system for vegetative cover. There are a number of systems extant now and confusion arises in determining equivalents. For this reason cross referencing of such systems as Brown, Lowe and Pase. Daubenmire and Radford schemes will be included to assist users in ascertaining the equivalanet plant association or community type. Common names are not being included within the data base since there are many variations of common names and some species do not have a common name. Also, it would require additional storage space and increased data input time. This conversion would be made only upon request.

The Natural Resources Department is interested in cooperating with other agencies in the gathering of this information. The use of this system by many agencies can only enhance the usability of the system. The Natural Resources Department is also interested in cooperative agreements for use of the system and access to its information. The interested agency may have a terminal in its own office, doing all input, updating and editing; or the Natural Resources Department could contract to do those operations, allowing access to the agency for all of the information.

III. The New Mexico State Heritage Program

History - the New Mexico State Heritage Program began in January of 1976 through a cooperative agreement between the New Mexico State Planning Office, the Federal Bureau of Outdoor Recreation (now the Heritage Conservation and Recreation Service) and the Nature Conservancy, the latter being a private, non-profit organization devoted to the preservation of natural diversity through land conservation and protection.

The scope, products and duration of the initial twelve month contract was amended and expanded as the Heritage Program developed. An amended contract was developed for fourteen months and then again extended from March 1, 1977 to July 1, 1977 by the Nature Conservancy. On July 1, 1977 the Heritage Program was assimilated into the New Mexico Game and Fish Department by earlier action of the New Mexico State Legislature in the Spring of 1977. The program was again transferred to the newly created Natural Resources Department on July 1, 1978 by action of the state's legislature in the Spring of that year. The New Mexico State Heritage Program was established to contribute to the preservation of the ecological diversity of New Mexico.

Concept of New Mexico State Heritage Program - The New Mexico State Heritage Program employs a sophisticated, efficient economical data management system capable of providing the State of New Mexico with an informational tool (LCD subsystem of HISS) that identifies, describes and locates the irreplaceable components of New Mexico's natural diversity. In addition, the program provides guidelines for data analysis, its use and comprehensive planning for the protection of priority sites which have emerged from the data.

The methodology of the Heritage inventory is innovative. A major shortcoming of most previous inventories has been the limitation imposed upon research workers by the arbitrary site-by-site approach. Each site is unique, due to unduplicated characteristics, or to the combination and spatial distribution of its habitats, species and other components.

In an attempt to resolve the problem, many inventories have relied upon quantitative evaluation systems that have proven to be both inflexible and complicated. In addition, the result has often been to submerge consideration of natural diversity while over emphasizing such features as degree of disturbance, scenic values, etc. Thus a limited spectrum of ecosystems, landscape types or elements which are well represented may become frequent objects of preservation interest, while passing over the few remaining examples of truly endangered elements.

In order to avoid such problems, the Heritage Program methodology focuses first upon the elements of diversity themselves. (an element of diversity, as defined by the Heritage inventory is a natural

feature of particular interest either because it is unique, exemplary, or endangered on a statewide basis.) A classification of element types is developed, including plant communities, geological features, as well as endangered or otherwise special plant and animal species. The list can be expanded by addition or subdivision of elements or by incorporating new classes of elements, such as cultural features, whenever it is deemed necessary. By dividing the nominated natural area sites into their components, it is possible to create element-based files in order to collect and enumerate reported occurrences of specific elements.

The element file structure provides an index relative rarity by showing the number of reported occurrences; and the index becomes more accurate as the system accumulates data. For this reason, it is important to bear in mind that the Heritage inventory is continually being modified, analyzed and supplemented. As more information is added and the data base is upgraded and refined, the program will become an increasingly rich repository of information.

Criteria for Selection of Natural Areas - The intent and purpose of the New Mexico State Heritage Program is to provide protection for a full array of irreplaceable components (elements) of New Mexico's natural diversity and to shelter element occurrences in the existing landscape. To provide this protection, it must first be determined what elements in the state are in need of protection. A classification system has been developed based upon a list of elements considered to be important. This system is used as a guide to data collection in order to obtain representative examples of each element in the classification system. The classification system is dynamic, allowing for constant change as new information becomes available. Continuing analysis of the data base determines how many occurrences have been documented for each element, and for which elements no occurrences have yet been documented. Some occurrences are documented while others may be found to be either poor sources or old or no longer relevant and are eliminated. As the Program continues, efforts will be concentrated on obtaining as many new occurrences for each element as possible and verifying the status of those occurrences presently in the system.

The Heritage Program provides an excellent tool for the preservation of the widest possible array of natural diversity. For example, using Heritage methodology, it is possible to locate areas containing elements which are as yet unrepresented on any protected lands. Such areas, if protected, will make the greatest contribution toward preserving the state's natural diversity. Moreover, by creating what amounts to a dynamic atlas on the existence, numbers, conditions, status, location, and distribution of the elements of ecological diversity, alternatives for action by various concerned parties are made clear. In this way the state's diverse heritage can be monitored and hopefully perpetuated.

The Heritage data base presently contains nearly 3000 element occurrences and has obtained approximately 250 users from the private sector as well as local, state and federal agencies and related public entities.

RESUMEN

El Departamento de Recursos Naturales de Nuevo Méjico ha iniciado el desarrollo de un amplio sistema de planificación de recursos naturales. Este sistema está diseñado para proveer información de tal forma que los encargados de hacer decisiones puedan tener la data y los sistemas analíticos necesarios para poder hacer decisiones oportunas y verificables según surjan los problemas de recursos naturales.

Ensayo de una Metodología para Elaborar una Tabla de Rendimiento de Peso de Hojas y Peso de Fibra Seca de "Datilillo" (Yucca valida)[1]

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Jorge Ham T.[2]

Resumen.- La falta de información sobre el potencial de los diferentes tipos de productos, que pueden derivarse de muchas de las especies del desierto, representa una fuerte limitante para planificar su adecuado aprovechamiento. Se describe aquí el proceso metodológico para elaborar una tabla de rendimiento de fibra de Yucca valida, de aplicabilidad en la determinación del potencial fibroso de las hojas de esta especie.

GENERALIDADES

La vegetación desértica de México se ubica básicamente en los Estados del Norte de la República, y se estima que cubre aproximadamente un 40% de la superficie total del país. El dato anterior expresa una idea general de la importancia que representa este recurso, sobre el cual incide una porción importante de la población, que en gran medida es de extracción campesina que de alguna manera participa del aprovechamiento de muchas especies útiles.

Este aprovechamiento se realiza a escalas doméstica y/o comercial, y hasta la fecha no se han aplicado técnicas adecuadas que permitan la conservación del recurso, provocándose la reducción gradual de las poblaciones de especies útiles, que en algunos casos, adquiere proporciones alarmantes.

Esta situación condiciona fuertemente la actividad económica de muchos núcleos campesinos, que dependen en gran medida de la explotación de especies como la candelilla, la lechuguilla, el guayule, el izote y otras, y cuya acción genera la disminución paulatina de la producción, situación que de continuar, llevará a la extinción de varias fuentes de trabajo y planteará un problema socio-económico a mediano plazo, amén de las implicaciones de orden ecológico que requieren a futuro de fuertes erogaciones para restablecer su equilibrio.

El problema expuesto anteriormente es bastante complejo, ya que por un lado la necesidad de subsistencia de los habitantes de estas Regiones, no permite que se pueda detener este sistema de aprovechamiento y por el otro, la escasez de información sobre técnicas y métodos, impiden un apropiado manejo de las poblaciones silvestres a nivel comercial. Esta problemática determina la necesidad de iniciar de inmediato, la evaluación de la potencialidad del recurso en estado silvestre para derivar sistemas concretos de manejo, y al mismo tiempo, iniciar ó continuar los estudios para implementar métodos de domesticación de especies de utilidad actual y potencial.

La poca información sobre el inventario de especie y producto, incide directamente en la problemática que plantea la evaluación de este recurso, y establece un reto a los profesionales forestales en relación a la derivación de métodos prácticos y eficientes de aplicación a nivel nacional, regional y local.

INTRODUCCION

De muchas de las plantas del desierto mexicano, pueden obtenerse productos de múltiples aplicaciones en diferentes áreas de la actividad económica. Las especies que integran el género Yucca que forman parte del matorral xerófilo característico de las zonas áridas - representan un ejemplo concreto de especies útiles, ya que de éstas pueden obtenerse productos que ofrecen una alternativa prometedora de explotación a nivel comercial. Uno de los productos provenientes de este género es la fibra contenida en sus hojas y troncos, cuyas características la hacen adecuada para muchos propósitos como cordelería, cestería,

[1] Trabajo presentado en el Evento Internacional "Inventarios de Recursos de Tierras Aridas", La Paz, B.C.S., México, Nov. 30 - Dic. 6, 1980.

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artesanias, costalería, producción de celulosa, - etc.

En relación a la fibra proveniente de las especies del género *Yucca* y otros, conviene indicar que a pesar de contar con extensas zonas del país cubiertas con este tipo de especies, se carece de estudios que aporten información sobre el potencial fibroso existente en las regiones desérticas. Además, no han podido detectarse inventarios de - este producto, y en consecuencia, no se conocen - tablas de rendimiento, que pudieran aplicarse a - la estimación de las existencias de fibra.

La panorámica anterior enmarca la situación actual de un recurso que representa una alternativa, que puede manejarse para mejorar la situación económica de muchas familias campesinas. Esta -- problemática lleva implícita la necesidad urgente de desarrollar estudios, enfocados a la cuantificación de productos de las especies desérticas.

El presente estudio tiene por objeto ensayar una metodología que permita establecer una relación entre el peso de las hojas verdes y el peso de la fibra seca contenido en las rosetas de la - especie *Yucca valida*. La relación para las dos variables anteriores, se pretende desarrollar mediante el establecimiento de clases, mismas que - se definirán como una combinación de agrupaciones de valores de diámetros y longitudes de rosetas.

Finalmente, se pretende estructurar dos tablas de doble entrada que proporcionen los valores peso de hojas y peso de fibra seca, para clases de roseta de 10 en 10 cm. Para el logro de - lo anterior, las variables involucradas se someterán a un proceso de regresión múltiple que permitirá la obtención de una ecuación de ajuste, mediante la cual se generarán los valores para construir las tablas.

ANTECEDENTES

El género *Yucca* ampliamente distribuído en el norte de la República Mexicana, ha sido motivo de numerosos estudios de órden específico y general normalmente orientados hacia aspectos florísticos, y en las últimas fechas enfocados desde el punto de vista de la fito-química.

Se han descrito alrededor de 30 especies para este género, presentandose en la actualidad, diferencias entre los especialistas en relación a la taxonomía de algunos de sus representantes. En - este sentido, Trelease (1902), Mc Kelvey (1930), - Webber (1953), y Trelease y Standley (1920), han desarrollado algunas clasificaciones, siendo estos dos últimos autores, los primeros que reconocieron 21 especies para México. En forma reciente, - Matuda y Piña (1980) elaboraron una clave para la identificación de los elementos que integran este género en nuestro país, estableciendo 30 diferentes especies distribuidas en las regiones áridas del territorio nacional.

A estos dos últimos autores se debe un estudio profundo sobre el género, en el que describen las características de sus diferentes componentes y los usos de sus productos. Este trabajo se originó en base a la importancia económica de la mayoría de sus especies, en relación a las substancias químicas que pueden extraerse de sus frutos, tallos, raíces y hojas. Sin embargo, también hacen énfasis en la obtención de productos de uso - tradicional, en especial la fibra generada de sus hojas, a partir de las que pueden confeccionarse una gran cantidad de artículos como son sandalias hamacas, cuerdas, cepillos, bolsos, etc.; se proporciona finalmente alguna información sobre otras aplicaciones de estas plantas entre los que se -- mencionan contención de taludes, construcción y - ornamentación.

Ridaura (1980) descripción de los usos actuales y potenciales de los productos que pueden obtenerse del género *Yucca*, dando gran importancia a las saponinas de múltiple aplicación industrial y a la producción de fibra proveniente fundamentalmente de las hojas. Sobre lo último, destaca el hecho de que su explotación no implica el peligro de la desaparición gradual de las especies como en otros casos, debido a que la producción de hojas es renovable en las plantas.

La mayoría de los estudios como los aquí expuestos, no integran en su desarrollo aspectos de cuantificación y evaluación del recurso. Al respecto cabe mencionar que existen pocos avances en cuanto a la derivación de metodologías aplicables al inventario de vegetación árida, y son muy escasas las experiencias sobre la elaboración de tablas específicas, para cuantificar el potencial - fibroso de las diferentes especies del género - - *Yucca*.

En relación a este último aspecto, se puede mencionar el estudio llevado a cabo por Marroquin Borja, Velázquez y De la Cruz (1964) en el que se integró parte de los estados de San Luis Potosí, - Zacatecas, Coahuila y Nuevo León en una zona de - 100 Km^2 cuyo objetivo fué el de determinar la posibilidad de obtener celulosa con fines industriales, a partir de las especies *Yucca filifera* y -- *Yucca decipiens*. En forma parcial, la información obtenida en sitios de muestreo de 0.1 Ha, a 0.25 Ha, sirvió para elaborar tablas que se aplicaron al cálculo de volúmenes de ramas para individuos en pies. Además, en base al derribo de algunos ejemplares, se generaron valores medios de peso de hojas verdes y secas, mismos que se utilizaron para estimar sus correspondientes totales para toda el área de estudio.

En la actualidad, la Dirección General del - Inventario Forestal procura elaborar Tablas de -- aplicación a la estimación de existencias de productos para algunas especies útiles del Estado de Coahuila, tomando como base la información obtenida de un inventario piloto de la vegetación desértica en una zona de 2000 Ha.

PROPOSITOS DEL ESTUDIO

Objetivo

El objetivo básico del estudio, consiste en desarrollar una metodología general para estructurar una tabla de rendimiento de peso de hojas verdes y peso de fibra seca de la especie Yucca valida, en función de categorías de diámetro y longitud de rosetas.

Metas a Alcanzar

Las metas que se pretenden lograr mediante el desarrollo de este estudio, son las siguientes:

- Aplicar el método de regresión múltiple para correlacionar las variables diámetro y longitud de roseta, con el fin de derivar las ecuaciones óptimas de ajuste de los datos.

- Elaborar sendas tablas de doble entrada, que proporcionen el peso de hojas verdes y el peso de fibra seca, para categorías de diámetro y longitud de roseta de 10 cm en 10 cm.

- Establecer el procedimiento metodológico general para estructurar este tipo de tablas a nivel nacional y regional, de aplicabilidad a diferentes especies del género Yucca, y probablemente para otras especies de generos afines.

- Aplicar la tabla elaborada a los datos generados para rosetas, del estudio "Ensayo de cinco esquemas de muestreo aplicados al inventario de datilillo y cardón", con objeto de estimar las existencias de fibra para la especie Yucca valida, y de este modo comprobar la utilidad práctica de la misma.

CRITERIOS Y METODOS

Area de estudio

Para la implantación de este trabajo se utilizó la misma zona en la que se desarrolló el correspondiente "Ensayo de cinco esquemas aplicados al inventario de datilillo y cardón", misma que se encuentra localizada en la parte sur de la Península de Baja California en lo que se conoce como Región de Los Cabos, la cual forma parte del desierto de Sonora. Dicha zona se encuentra enclavada parcialmente en el Campo Experimental Forestal "Todos Santos", perteneciente al Instituto Nacional de Investigaciones Forestales.

Estructura de la Tabla

Con el objeto de proponer una estructura preliminar para las tablas propuestas, se procedió al análisis de la información derivada del primer estudio a que se ha hecho referencia en párrafos anteriores, obteniéndose primeramente los rangos de los valores para diámetro y longitud de roseta de los individuos que quedaron incluídos en los muestreos.

A continuación se establecieron clases adecuadas de rosetas, es decir, éstas se constituyeron como una combinación de clases de longitud y diámetro de las mismas, tratando de cubrir todas las posibilidades para éstas dos variables. Por último, se procedió a elaborar un cuadro preliminar de clases de rosetas.

Tamaño de Muestra

Para determinar el tamaño de la muestra se siguió el procedimiento siguiente: 1) se graficaron primeramente los valores correspondientes al número promedio de individuos, contra 36 clases de rosetas (de 30 en 30 cm), obteniendose una tendencia hacia una curva normal, misma que proporcionó valores ajustados para las clases de rosetas consideradas. 2) después se calculó el tamaño de muestra en base a la mayor frecuencia observada, preestableciendo un error de muestreo del 10%, utilizando para ello la fórmula estadística de la distribución uniforme, de la que se obtuvo un valor de 50 individuos por clase de roseta como tamaño de muestra aproximada y 3) finalmente, pese a que la distribución uniforme indicó que debían tomarse 50 individuos por clase, esta cifra no pudo cubrirse en el terreno para las clases extremas, como lo demostró el proceso gráfico.

Muestreo

Para obtener la información que sirvió de base para elaborar las tablas, se uso el esquema de muestreo aplicado en la caracterización del testigo del estudio ya mencionado anteriormente, por último, se procedió a recorrer todos los conglomerados y sus correspondientes sitios de muestreo hasta que se obtuvo un número de rosetas por clase próximo al estimado en el punto anterior.

Información Recabada

La información aplicada a la construcción de la tabla fué la siguiente:

1. Información generada en los sitios de muestreo

   1.1. para individuos

   - altura total
   - diámetro fustal

   1.2. para rosetas

   - longitud
   - diámetro
   - clase a la que pertenece
   - número de hojas

   1.3. tiempos

   - de levantamiento del sitio
   - de deshojado, atado, control y etiquetado de hojas por roseta.

2. Información generada en las instalaciones del Campo Experimental.

   2.1. Para rosetas

   — peso de hojas por roseta
   — peso de fibra

   2.2. Tiempos

   — de pesado de hojas
   — de machacado de hojas
   — de cocido de hojas
   — de fermentado de hojas
   — de desfibrado de hojas
   — de secado de fibra
   — de pesado de fibra.

Desarrollo de los Trabajos

La altura total del individuo así como la longitud y diámetro de la roseta se midieron con pértiga graduada al centímetro (Fig. 1), en cambio para el diámetro del fuste se utilizó cinta-diamétrica.

Figura 1. Uso de la pértiga para medir el diámetro de la roseta con aproximación al centímetro.

Las hojas de cada roseta se obtuvieron mediante desprendimiento por jalón directo (Fig. 2), procediendo enseguida a contarlas y atarlas con una cuerda. Al manojo resultante se le colocó una etiqueta en la cual se inscribieron los siete datos siguientes: números de conglomerado, de sitio y de individuo; fecha, nombre del jefe de brigada, clase de roseta y total de hojas. Con el objeto de dañar al mínimo la planta, se extrajo aproximadamente un 70% del total de hojas de cada roseta, iniciando un deshoje sobre aquellas que no manifestaron síntomas de marchitamiento y avanzando hacia arriba hasta llegar a las muy tiernas.

Figura 2. Método utilizado para desprender las hojas de la roseta.

Figura 3. Constitución de los manojos de hojas después de haberlas contado.

Para obtener la fibra se realizaron las cinco pruebas siguientes:

Pruebas en Crudo:

1. Fermentado, desfibrado y secado.
2. Machacado, fermentado, desfibrado y secado.

Pruebas en Cocido:

3. Cocido, fermentado, desfibrado y secado.
4. Cocido, machacado, fermentado, desfibrado y secado.
5. Machacado, cocido, fermentado, desfibrado y secado.

La prueba que proporcionó los mejores resultados en relación a reducción del tiempo de obtención de fibra, fue la mencionada al final.

El machacado consistió en golpear cada una de las hojas con un mazo de madera, con el obje-

to de romper la cutícula y remover la parte carnosa de las mismas.

El cocido de los manojos de hojas (Fig. 4), se llevó a cabo en recipientes con agua, la cual se sometió al punto de ebullición durante una hora, con lo que se consiguió el reblandecimiento de la parte carnosa de las hojas.

Figura 4. Procedimiento de cocido de hojas.

La operación de fermentado se realizó en piletas llenas de agua (Fig. 5), en las cuales se introdujeron los manojos de hojas permaneciendo en éstas durante siete días; lo anterior, provocó la descomposición de la parte carnosa de la hoja.

Figura 5. Descomposición de las hojas por medio de la acción del agua.

El desfibrado consistió en eliminar la parte carnosa de cada una de las hojas, por medio de un tallador de madera, obteniéndose la fibra húmeda con residuos carnosos poco considerables.

El secado de la fibra se efectuó al aire libre (Fig. 6). Para lo anterior, los manojos de fibra se esparcieron sobre un entarimado, permaneciendo en ésta durante un período de tres a siete días. La variación en el tiempo de secado, dependió del tamaño de los manojos (Fig. 7) y de la cantidad de sol que se presentó durante el día.

Figura 6. Método aplicado al secado de la fibra.

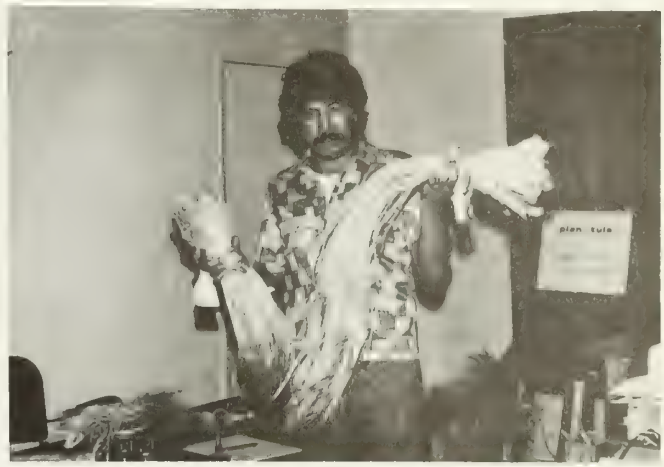

Figura 7. Variación en el tamaño de los manojos de fibra seca.

Para generar los valores de peso de hojas verdes y peso de fibra seca (Fig. 8), se utilizaron balanzas con precisión al gramo.

Para obtener los manojos de hojas se utilizó una brigada integrada por un Guarda Técnico Forestal y dos operarios, mientras que para realizar las actividades en las instalaciones del Campo Experimental se necesitaron trece operarios, quienes ejecutaron éstas, según aptitudes y necesidades.

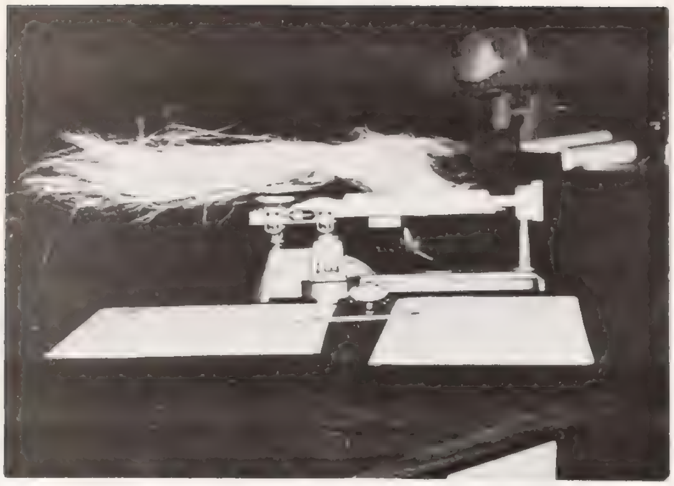

Figura 8. Pesado de los manojos de fibra seca.

RESULTADOS Y DISCUSION

Para elaborar las tablas propuestas se utilizó un análisis de regresión lineal múltiple, correlacionando las variables peso de hojas verdes y peso de fibra seca con los correspondientes valores de las variables diámetro y longitud de roseta para categorías de 10 en 10 cm; para lo anterior, se consideró a las primeras como variables dependientes y a las segundas como variables independientes.

Por medio del procedimiento mencionado se obtuvieron los valores estadísticos necesarios para interpretar los resultados, mismos que se presentan en la Tabla 1.

Tabla 1. Estadísticos obtenidos de la regresión lineal múltiple de las variables peso de hojas verdes y peso de fibra seca.

ESTADISTICOS	PESO DE HOJAS VERDES	PESO DE FIBRA SECA
MEDIAS	$Y = 1747.86541$ $X_1 = 77.72457$ $X_2 = 108.35524$	$Y = 215.04272$ $X_1 = 77.72457$ $X_2 = 108.35524$
VARIANZAS	$Y = 1844460.82642$ $X_1 = 875.44738$ $X_2 = 1370.32936$	$Y = 27686.33427$ $X_1 = 875.44738$ $X_2 = 1370.32936$
DESVIACIONES ESTANDARD	$Y = 1358.10928$ $X_1 = 29.58796$ $X_2 = 37.01796$	$Y = 166.39211$ $X_1 = 29.58796$ $X_2 = 37.01796$
COEFICIENTES DE REGRESION	$A_0 = 1280.86437$ $A_1 = 26.87900$ $A_2 = 8.67121$	$A_0 = 154.52172$ $A_1 = 3.12399$ $A_2 = 1.16979$
ERRORES STANDARD DE ESTIMACION	894.19932	111.43047
COEFICIENTES DE CORRELACION	0.75356 AJUST. 0.75266	0.74359 AJUST. 0.74264
F ESTADISTICA	417.85	393.29

Las ecuaciones que se derivaron de las funciones PHV = f(d·l) y PFS = f(d·l), fueron las siguientes:

$$PHV = -1280.86437 + 26.87900(X_1) + 8.67121(X_2)$$
$$PFS = -154.52172 + 3.12399(X_1) + 1.16979(X_2)$$

En donde:

PHV = Peso de hojas verdes.
PFS = Peso de fibra seca.
$d = X_1$ = Diámetro de la roseta.
$l = X_2$ = Longitud de la roseta.

−1280.86437
26.87900 Coeficientes de regresión para PHV
8.67121

− 154.52172
3.12399 Coeficientes de regresión para PFS
1.16979

Los análisis de varianza de los valores de la regresión, para peso de hojas verdes y peso de fibra seca se presentan en la Tabla 2.

Tabla 2.- Análisis de varianza para los valores peso de hojas verdes y peso de fibra seca.

FV	GL	SC	CM	F
		PESO DE HOJAS VERDES		
REGRESION	2	668225207.37	334112603.69	417.85
RESIDUAL	636	508540787.08	799592.43	
TOTAL	638	1176765994.45		
		PESO DE FIBRA SECA		
REGRESION	2	9766827.28	4883413.64	393.29
RESIDUAL	636	7897053.42	12416.75	
TOTAL	638	17663880.70		

En relación a los coeficientes de correlación, se observa que existe una asociación adecuada entre las tres variables involucradas en cada función, debido a que los valores que proporcionó la tabla de distribución fueron 0.109 al 5% y 0.135 al 1%, considerando los grados de libertad dados (n-2 = 637).

Por lo que se refiere al valor de la F, ambos cuadros de análisis de varianza muestran valores altos en comparación con los valores tabulados (tomando como base de entrada a la tabla los grados de libertad de la regresión y del residual), aún al 1% de confiabilidad.

Los resultados finales del estudio se presentan en las Tablas 3 y 4.

TABLA 3. TABLA QUE PROPORCIONA EL PESO DE HOJAS VERDES (EN GRAMOS) EN FUNCION DE CLASES DE DIAMETRO Y LONGITUD DE ROSETA DE LA ESPECIE *Yucca valida* PARA EL CAMPO EXPERIMENTAL FORESTAL "TODOS SANTOS", BAJA CALIFORNIA SUR.

DIAMETRO DE ROSETA cm. / LONGITUD DE ROSETA cm.	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	150	170	180	190	200
10					149.80	418.59	687.38	956.17	1224.96	1493.75	1762.54	2031.33	2300.12	2568.91	2837.70	3106.49	3375.28	3644.07	3912.86	4181.65
20					236.51	505.30	774.09	1042.88	1311.67	1580.46	1849.25	2118.04	2386.83	2655.62	2924.41	3193.20	3461.99	3730.78	3999.57	4268.36
30				54.43	323.22	592.01	860.80	1129.59	1398.38	1667.17	1935.96	2204.75	2473.54	2742.33	3011.12	3279.91	3548.70	3817.49	4086.28	4351.07
40				141.14	409.93	678.72	947.51	1216.30	1485.09	1753.88	2022.67	2291.46	2560.25	2829.04	3097.83	3366.62	3635.41	3904.20	4172.99	4441.78
50				227.86	496.65	765.44	1034.23	1303.02	1571.81	1840.60	2109.39	2378.18	2646.97	2915.76	3184.55	3453.34	3722.13	3990.92	4259.71	4528.50
60			45.78	314.57	583.36	852.15	1120.94	1389.73	1658.52	1927.31	2196.10	2464.89	2733.68	3002.47	3271.26	3540.05	3808.84	4077.63	4346.42	4615.21
70			132.49	401.28	670.07	938.86	1207.65	1476.44	1745.23	2014.02	2282.81	2551.60	2820.39	3089.18	3357.97	3626.76	3895.55	4164.34	4433.13	4701.92
80			219.20	487.99	756.78	1025.57	1294.36	1563.15	1831.94	2100.73	2369.52	2638.31	2907.10	3175.89	3444.68	3713.47	3982.26	4251.05	4519.84	4788.63
90		37.13	305.92	574.71	843.50	1112.29	1381.08	1649.87	1918.66	2187.45	2456.24	2725.03	2993.82	3262.61	3531.40	3800.19	4068.98	4337.77	4606.56	4875.35
100		123.84	392.63	661.42	930.21	1099.00	1467.79	1736.58	2005.37	2274.16	2542.95	2811.74	3080.53	3349.32	3618.11	3886.90	4155.69	4424.48	4693.27	4962.06
110		210.55	479.34	748.13	1016.90	1285.71	1554.50	1823.29	2092.08	2360.87	2629.66	2898.45	3167.24	3436.03	3704.82	3973.61	4242.40	4511.19	4779.98	5048.77
120	28.47	297.26	566.05	834.84	1103.63	1372.42	1641.21	1910.00	2178.79	2447.58	2716.37	2985.16	3253.95	3522.74	3791.53	4060.32	4329.11	4597.90	4866.69	5135.48
130	115.18	383.97	652.76	921.55	1190.34	1459.13	1727.92	1996.71	2265.50	2534.29	2803.08	3071.87	3340.66	3609.45	3878.24	4147.03	4415.82	4684.61	4953.40	5222.19
140	201.90	470.68	739.48	1008.27	1277.06	1545.85	1814.64	2083.43	2352.22	2621.01	2889.80	3158.59	3427.38	3696.17	3964.96	4232.75	4502.54	4771.33	5040.12	5308.91
150	288.61	557.40	826.19	1094.98	1363.77	1632.56	1901.35	2170.14	2438.93	2707.72	2976.51	3245.30	3514.09	3782.88	4051.67	4320.46	4589.25	4858.04	5126.83	5395.62
160	375.32	644.11	912.90	1181.69	1450.48	1719.27	1988.06	2256.85	2525.64	2794.43	3063.22	3332.01	3600.80	3869.59	4138.38	4407.17	4675.96	4944.75	5213.54	5482.33
170	462.02	730.82	999.61	1268.40	1537.19	1805.98	2074.77	2343.56	2612.35	2881.14	3149.93	3418.72	3687.51	3956.30	4225.09	4493.88	4762.67	5031.46	5300.25	5569.04
180	548.74	817.53	1086.32	1355.11	1623.90	1892.69	2161.48	2430.27	2699.06	2967.85	3236.64	3505.43	3774.22	4043.01	4311.80	4580.59	4849.38	5118.17	5386.96	5655.75
190	635.46	904.25	1173.04	1441.83	1710.62	1979.41	2248.20	2516.99	2785.78	3054.57	3323.36	3592.15	3860.94	4129.73	4398.52	4667.31	4936.10	5204.89	5473.68	5742.47
200	722.17	990.96	1259.75	1528.54	1797.33	2066.12	2334.91	2603.70	2872.49	3141.28	3410.07	3678.86	3947.65	4216.44	4485.23	4754.02	5022.81	5291.60	5560.39	5829.18

TABLA 4. TABLA QUE PROPORCIONA EL PESO DE FIBRA SECA (EN GRAMOS EN FUNCION DE CLASES DE DIAMETRO Y LONGITUD DE ROSETA PARA LA ESPECIE *Yucca valida* EN EL CAMPO EXPERIMENTAL FORESTAL "TODOS SANTOS", BAJA CALIFORNIA SUR.

DIAMETRO DE ROSETA cm. / LONGITUD DE ROSETA cm.	10	20	30	40	50	60	70	80	90	100	[illegible]	120	130	140	150	160	170	180	190	200
10					13.38	44.62	75.86	107.10	138.34	169.58	200.[illegible]	232.06	263.30	294.54	325.78	357.02	388.26	419.50	450.74	481.98
20					25.07	56.31	87.55	118.79	150.03	181.27	212.[illegible]	243.75	274.99	306.23	337.47	368.71	399.95	431.19	462.43	493.67
30				5.53	36.77	68.01	99.25	130.49	161.73	192.97	224.[illegible]	255.45	286.69	317.93	349.17	380.41	411.65	442.89	474.13	505.37
40				17.23	48.47	79.71	110.95	142.19	173.43	204.67	235.[illegible]	267.15	298.39	329.63	360.87	392.11	423.35	454.59	485.83	517.07
50				28.93	60.17	91.41	122.65	153.89	185.13	216.37	247.[illegible]	278.85	310.09	341.33	372.57	403.81	435.05	466.29	497.53	528.77
60			9.39	40.63	71.87	103.11	134.35	165.59	196.83	228.07	259.[illegible]	[illegible]	321.79	353.03	384.27	415.51	446.75	477.99	509.23	540.47
70			21.08	52.32	83.56	114.80	146.04	177.28	[illegible]	239.76	271.[illegible]	[illegible]	333.48	364.72	395.96	427.20	458.44	489.68	520.92	552.16
80			32.78	64.02	95.26	126.50	157.74	188.98	220.22	251.46	282.[illegible]	[illegible]	345.18	376.42	407.66	438.90	470.14	501.38	532.62	563.86
90		13.24	44.48	75.72	106.96	138.20	169.44	200.68	231.92	263.16	294.[illegible]	325.64	356.88	388.12	419.36	450.60	481.84	513.08	544.32	575.56
100		24.94	56.18	87.42	118.66	149.90	181.14	212.38	243.62	274.86	306.[illegible]	337.34	368.58	399.82	431.06	462.30	493.54	524.78	556.02	587.26
110		36.63	67.87	99.11	130.35	161.59	192.83	224.07	255.31	286.55	317.[illegible]	349.03	380.27	411.51	442.75	473.99	505.23	536.47	567.71	598.95
120	17.09	48.33	79.57	110.81	142.05	173.29	204.53	235.77	267.01	298.25	329.[illegible]	360.73	391.97	423.21	454.45	485.69	516.93	548.17	579.41	610.65
130	28.79	60.03	91.27	122.51	153.75	184.99	216.23	247.47	278.71	309.95	341.[illegible]	372.43	403.67	434.91	466.15	497.39	528.63	559.87	591.11	622.35
140	40.49	71.73	102.97	134.21	165.45	196.69	227.93	259.17	290.41	321.65	352.[illegible]	384.13	415.37	446.61	477.85	509.09	540.33	571.57	602.81	634.05
150	52.19	83.43	114.67	145.91	177.15	208.39	239.63	270.87	302.11	333.35	364.[illegible]	395.83	427.07	458.31	489.55	520.79	552.03	583.27	614.51	645.75
160	63.88	95.12	126.36	157.60	188.84	220.08	251.32	282.56	313.80	345.04	376.[illegible]	407.52	438.76	470.00	501.24	532.48	563.72	594.96	626.20	657.44
170	75.58	106.82	138.06	169.30	200.54	231.78	263.02	294.26	325.50	356.74	387.[illegible]	419.22	450.46	481.70	512.94	544.18	575.42	606.66	637.90	669.14
180	87.28	118.52	149.76	181.00	212.24	243.48	274.72	305.96	337.20	368.44	399.[illegible]	430.92	462.16	493.40	524.64	555.88	587.12	618.36	649.60	680.84
190	98.98	130.22	161.46	192.70	223.94	255.18	286.42	317.66	348.90	380.14	411.[illegible]	442.62	473.86	505.10	536.34	567.58	598.82	630.06	661.30	692.54
200	110.68	141.92	173.16	204.40	235.64	266.88	298.12	329.36	360.60	391.84	423.[illegible]	454.32	485.56	516.80	548.04	579.28	610.52	641.76	673.00	704.24

CONCLUSIONES

— Las tablas obtenidas presentan una confiabilidad adecuada, como lo demuestran algunos valores estadísticos, a pesar de que los datos para su elaboración se recabaron en una zona de 400 Ha. heterogénea en cuanto a fisiografía, sin considerar además, la variabilidad propia de la especie (edad, vigor, variedad, etc).

— Creemos que las tablas proporcionarán resultados confiables de peso de hojas verdes y peso de fibra seca para la especie Yucca valida, tanto para el área de estudio, como para zonas con características similares.

— Es posible que estas tablas pudieran proporcionar estimaciones adecuadas para las dos variables de la especie considerada, en inventarios a nivel nacional y regional, mediante una comprobación previa de la bondad de la misma.

— La metodología aquí desarrollada, podría aplicarse a la estructuración de tablas similares tanto para otras especies del género Yucca, como para especies de generos afines, efectuándolos ajustes necesarios en cada caso.

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ABSTRACT

The lack of information on the possible uses for the various types of products that could be obtained from many desert species is a limiting factor in planning for their suitable utilization. A systematic process for the preparation of a table of yields of fiber content of Yucca valida, which could be used to evaluate the fiber potential in the leaves of this species, is described.

Computer Simulation of Forage Allocation Between Big Game and Domestic Livestock[1]

Allen Y. Cooperrider[2] and James A. Bailey[3]

Abstract.--A computer model has been developed to simulate the grazing process. The model predicts consequences for forages and wild and domestic animals of decisions on a semiarid range in southern Colorado. The model provides an efficient method of integrating inventory data with basic biological data to assist managers in forage allocation decision making.

INTRODUCTION

A major value of arid lands has been the provision of forage for wild ungulates and domestic livestock. Often one or more species of wild or domestic ungulates coexist on the same ranges, in which case they may compete to some degree for available forage. Enlightened resource managers attempt to limit or control the degree of competition through forage allocation. Forage allocation decisions are implemented through control of the number of wild and domestic animals on the range. In the case of livestock, season of use and class of livestock may also be managed. This paper will trace the development of forage allocation methods for arid lands, discuss some problems with current methods, describe a computer simulation model that has been developed to assist managers in forage allocation, and illustrate how the model has been applied to an arid range in southern Colorado.

DEVELOPMENT OF FORAGE ALLOCATION SYSTEMS

Early Allocation Systems

Historically forage allocation to wildlife has been by default, i.e. livestock have been grazed with little or no concern for leaving forage available to wildlife. This has resulted in substantial reductions in wild ungulate populations in parts of the arid lands of Europe, Asia and Africa. Similarly, in North America many populations have been reduced due to excessive livestock grazing (Wagner 1979).

In the last 40 years there have been attempts to manage rangeland resources using quantitative systems. An early concern of North American range managers and rangeland management agencies was to limit numbers of domestic livestock so that forage use would not exceed a level that allowed range plants to reproduce and maintain productivity. Several systems were developed to predict such stocking rates. Most systems involved measuring the annual forage production, determining an allowable use level for each major plant species, adding allowable use for each species to calculate the amount of "usable" forage, and finally calculating the number of animals that could be supported based upon average forage intake rates. The number of animals that could be supported came to be quantified in animal unit months (AUM's) which were defined as the amount of forage necessary to support a cow and calf for 1 month. Equivalence figures were developed for other classes of livestock. Thus 8 sheep could be grazed for 1 month on 1 AUM whereas a horse required 1 1/2 AUM's for a month of grazing.

In the earliest attempts to allocate forage to wildlife as well as to livestock, allocation was usually based upon the AUM equivalent system. Thus AUM tables were developed and published for the major wild ungulate species (Rasmussen 1940 in Stoddart and Smith 1955). This was the most commonly used system until the 1970's and it is still being used in many places. However, such a simplified system is not adequate to handle many of the more complex forage allocation problems.

New Concepts

There has been much recent research on habitat use, food habits, nutrition, and population dynamics of wild and domestic ungulates as well as

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[1]Paper presented at the Arid Land Resource Inventories Workshop. [LaPaz, Mexico, November 30-December 6, 1980].

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on the physiology, response to grazing, and population dynamics of rangeland plants. This research has demonstrated the complexity of grazing land systems that man attempts to manage. Parallel advances have occurred in quantitative techniques such as optimization and simulation. These techniques have been applied to complex problems in natural resource management, including forage allocation. A few biological concepts and quantitative techniques related to forage allocation are described below.

Biological Concepts

Carpenter (1980) noted that traditional approaches to forage allocation were designed for allocating forage to one or more species of livestock and do not realistically represent the complex behavior and nutritional and habitat requirements of wild ungulates.

Forage Quality.-- Some early workers considered forage quality to be more important than quantity in determining carrying capacity for both livestock (Cook and Harris 1950) and wild ungulates (Leopold 1950). This contention is not universally accepted. Some contend that, due to the adaptability of large ruminants, forage quantity is more important than forage quality to these animals (Holechek 1980). However, much research and management on wild ungulates has demonstrated the importance of forage quality (Verme 1969, Ullrey et al. 1970) and much effort is being expended to develop carrying capacity models based on nutritional requirements (Moen 1973, Mautz 1979, Wallmo et al. 1977).

Population Dynamics.--All animals within a population are not equal with regard to forage intake rates and nutrient requirements. Adult wild ungulates require sufficient forage to maintain themselves above a starvation level; however, a maintenance level for individuals will not ensure maintenance of the population. Fluctuations in ungulate populations are largely determined by numbers of adult females that have adequate forage to produce viable offspring and the numbers of young that can survive to breeding age. Nutritional requirements for reproduction and growth are substantially higher than for maintenance. Thus, available forage must be sufficient in quantity and quality to provide for the needs of pregnant and lactating females and growing young animals and the sex-age structure of a wild ungulate population is an important consideration in forage allocation.

Foraging Behavior.--Foraging is an extremely complicated behavior. Species of wild ungulates have strong preferences and requirements for habitat types as well as for forage species and for parts of forage plants. These preferences and requirements vary seasonally. Realistic models of foraging must incorporate these considerations. A large body of theory has been developed to account for foraging behavior of animals (Schoener 1971, Pyke et al. 1977). Yet we are unable to predict with much precision how and where an animal will forage at a given time. Most food habits data suggest that ungulates, by eating the best and most preferred plant species, are continuously "high-grading" the forage supply. Thus, the time an animal utilizes a range determines the quality of forage that will be available and thus determines its food habits and nutritional intake.

Weather Patterns.--Weather strongly influences not only forage production but also forage availability to ungulates. Furthermore, weather patterns on arid western rangelands of the U.S. can be quite variable.

Quantitative Techniques

Application of quantitative techniques to forage allocation has been reviewed by Van Dyne and Kortopates (1980). Two major approaches have developed, optimization (Martinson and McPherson 1980, Nelson 1980) and simulation (Cooperrider and Bailey 1980). Optimization techniques generally use some form of mathematical programming to determine a mix of ungulates that will maximize utilization of forage up to a level of allowable use for plant species. Nelson (1980), however, applies competition theory to forage allocation through use of a formulary model.

Simulation approaches to forage allocation do not calculate optimal solutions. In simulation, a model of the forage-animal system is used to observe trends in major variables that will be affected by a variety of allocation decisions. Thus many situations can be simulated and the predicted consequences of alternative management decisions can be examined prior to goal-selection and management implementation.

COMPUTER SIMULATION MODEL

A computer simulation model has been developed to predict impacts of selective forage removal by free-ranging big game and domestic livestock. Impacts upon ungulates and upon forage resources are predicted. The model estimates forage removal from a set of habitat types as a function of the standing crops of forage, densities of big game and livestock, seasonal trends in animal distribution and forage preferences, weather patterns and previous forage removal. Predicted forage removal by ungulates is used to estimate trends in qualities of diets. Impacts upon weight changes, reproduction and mortality are predicted from diet qualities and nutritional requirements of animal species. The model is described in Cooperrider and Bailey (1980). Data bases required to utilize the model are described here with a brief description of the model's dynamics.

DATA BASES

Four types of data are utilized in our model; habitat data, population data, weather data, and basic biological data. The first three are site-specific data that should be collected or estimated for each area being modeled. They represent initial values of state variables in the model. Basic biological data, on the other hand, are more universal relationships used to define parameters which govern flows among state variables. For our allocation model the latter data have been gathered from the scientific literature.

A list of the major data bases that can be utilized by the model is provided in table 1. Not all of these data bases need be utilized. For example, the model can be run with or without data on snow depths. Also the submodels for plant dynamics and animal dynamics can be run independently.

Table 1. Major data bases of simulation model.

Type	Definition
Habitat Data	
Number of plants	The number of plants of each major species in each habitat type.
Weight per plant	The weight of current annual growth of a plant of each major plant species at each phenological stage.
Habitat preference	The relative preference of each animal species for each habitat type during each season.
Forage preference	The relative preference of each animal species for each plant species at each phenological stage.
Population Data	
Wild ungulate numbers	The number of animals of each wild ungulate species in each sex and age class.
Wild ungulate weights	The average weights of an animal of each wild ungulate species in each sex and age class.
Livestock numbers	The number of animals in each livestock class on each allotment.
Livestock weights	The average weight of each animal of each class of livestock.
Weather Data	
Snow depth	Base station snow depth (actual records summarized by 2-week periods).
Basic Biological Data	
Caloric density	The digestible energy content of each plant species for each phenological stage.
Birth rates	The average number of young produced by females of a given age class for each wild ungulate species.
Death rates	The average percentage of animals of each sex and age class of each wild ungulate species that die annually from disease, predation and accidents.

Habitat Data

Three types of "habitat" data need be collected for use in the model: forage production, habitat use, and food habits.

Forage Production.--Data on the number of plants per acre and the average weight of production per plant are collected for each major plant species within each stratum or habitat type on each livestock allotment.

Habitat Use.--The habitat sites used by each ungulate species and season are determined. The data may involve either a determination of "use" vs. "no-use" or a relative preference for each type.

Food Habits.--The percentage of each major plant species in the diet of each ungulate is determined by season. These data are gathered for the particular area being modeled through fecal analysis or other appropriate techniques. In a few cases, suitable data are available in the literature. The data are not used directly in the model but rather are used with forage production data to determine a relative preference index for each plant species in each season (Krueger 1972).

Population Data.--The numbers of ungulates in each sex and age class of each ungulate species are determined or estimated. The number of age classes utilized is specified by the user of the model. Generally, the number and classes of livestock on each allotment are known. Data on wild ungulates may be obtained from wildlife management agencies or must be estimated for the area. For meaningful simulations, at least 6 sex-age classes are distinguished: young of the year, yearlings, and adults, for each sex.

Weather Data.--Weather records may be used to increase realism of the model. For our test area we have used records of snow depths from a nearby base weather station and snow depth measurements on the range to develop predictive equations for determining average snow depth on each habitat site as a function of base station snow depth, and elevation and aspect at each site. This equation allows use of snow depth data from any of the past

25 years to simulate the distribution of snow on the range during severe, mild or average years. Snow depth data are used primarily to predict if forage is available to wild ungulates on each habitat site.

Records of temperature and precipitation may also be used to simulate the year-to-year variation in forage production as a function of effective precipitation, however, we have not developed this subprogram. The United States Bureau of Land Management (BLM) is currently sponsoring research to quantify this relationship.

Basic Biological Data

Data in this category are used primarily to quantify flows as opposed to providing initial values for state variables. Data include measurements of nutritional qualities of forages, nutritional requirements of ungulates, and population dynamics parameters for wild ungulates. These data tend to be less site-specific and we have taken values from the scientific literature. Model users would not normally have to determine or specify these on a site-specific basis, although they would have this option.

Dynamics

Dynamics of the model can be divided into 4 categories: plant dynamics, forage removal, animal dynamics and management.

Plant Dynamics

The weight of forage for each plant species within each habitat type on each allotment is calculated from the weight per plant for the appropriate phenological state, and the number of plants present. During the growing season, when phenological stages are changing, the available forage must be recalculated at each time interval.

Forage Removal

Foraging is simulated for each sex-age class at 2-week intervals. Several processes are simulated to mimic animal foraging: choice of habitat, choice of forage, feedback on plant species, and feedback on animals (growth).

Habitat Choice.--Habitat types or strata that are unavailable due to deep snow are first eliminated. Each simulated ungulate population then chooses an area based upon its relative preference for habitat types and the relative forage density in each type. In the case where habitat preference is expressed as "use" or "no-use" the population is simulated as choosing to forage in the type with the greatest density of preferred forages among those types in the "use" categories. Habitat choice is modeled in the same way for livestock as for wild ungulates, except that livestock are restricted to allotments.

Choice of Forage.--Once a habitat site is selected for foraging, forage is chosen as a function of the amount of each plant species present and the relative preference for the species at its phenological stage. The weight of each plant species in the diet is a function of total forage intake for the period and the percentage of the species in the diet. Forage intake can be made a function of body weight or metabolic body weight ($Wt^{0.75}$) where appropriate.

Plant Feedback.--The immediate short-term feedback is that as forage is removed, fewer plants are available to provide forage. These plants are not available to produce forage in the current year, however, they are available in future years or growing seasons. Long-term feedback can also be modeled in which the number of plants available in future years declines as a function of the degree to which the allowable use factor (AUF) for each species is exceeded.

Animal Feedback.--The major feedback effect on animals is a weight loss or gain calculated as a function of digestible energy intake and metabolic body weight.

Animal Dynamics

Two principal types of animal dynamics are simulated, birth and associated processes, and death.

Birth.--Birth of wild ungulates is modeled as a discrete event occurring on approximately June 1. At this time new animals are added to the first age class of each wild ungulate population. Births are a function of the number of reproductive females and specified age specific birth rates. Concurrently the remaining population is moved to new age classes. At this time the weights of females are reduced to account for birth. Similarly, the energy intakes and losses of lactating females and nursing young are adjusted to account for lactation. Both adjustments are made following procedures described in Cooperrider and Behrend (1980).

Death.--Three types of death are simulated: background mortality (predation, disease, accidents), starvation, and hunter kill. The latter will be discussed under management.

Background mortality is defined as the level of mortality that would occur in the absence of hunting and in the absence of any forage limitation on a herd. It is modeled as a function of the numbers of animals and the age- and sex-specific death rates.

Starvation death is modeled as a function of animal weight and can occur at any time of year. When animals of a given sex and age class lose more than a specified critical percentage of their

normal weight, they are considered to have starved and are removed from the population.

Management

Of the processes modeled few are subject to control by man. In practice the number, classes and seasons of grazing of livestock can be closely managed. Similarly, the number of wild ungulates in each species can be influenced through hunter harvest. Any combination of numbers, classes of livestock, and seasons of use can be simulated by the model. Hunting harvest can be simulated using harvest rates similar to the mortality rates described under death.

TRICKLE MOUNTAIN STUDY AREA

The model was developed using data from a semiarid range known as the Trickle Mountain study area. This area is located in south-central Colorado approximately 20 km west of Saguache. The study area is bounded on the north by the Continental Divide, on the south and west by Colorado Highway 114 and on the east by a line running south from Antora Peak. The area measures about 30 km by 15 km and consists of approximately 45% lands administered by the BLM and 45% U.S. Forest Service lands. The remaining 10% of land is privately owned, mostly at lower elevations along creeks.

Elevations range from 2,500 m along Saguache Creek to over 3,600 m along the Continental Divide. Vegetation varies from shortgrass types dominated by blue grama (*Bouteloua gracilis*) at the lower elevations to pinon-juniper, ponderosa pine, Douglas fir and subalpine meadow types. Physiography of the area is characterized by numerous rocky outcrops and talus cliffs, these areas being favored by bighorn sheep. Common understory species on these areas are blue grama, fescues (*Festuca* sp.), muhly's (*Muhlenbergia* sp.), bluegrasses (*Poa* sp.), rabbitbrush (*Chrysothamnus* sp.), fringed sagebrush (*Artemisia frigida*), true mountainmahogany (*Cercocarpus montanus*), and pingue (*Hymenoxys richardsonii*).

The area is grazed year-round by bighorn sheep (*Ovis canadensis*) and pronghorn antelope (*Antilocapra americana*), and seasonally by mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), cattle, and horses. Data on forage production and on seasonal food habits and distribution of all 6 species have been collected for 2 years. These data, with data on ungulate population levels, weather patterns and basic ungulate biology are integrated in the computer model.

EXAMPLES

Examples are presented here to illustrate the types of "what if" questions that can be addressed by simulation and to demonstrate the insight into system dynamics that can be provided by such a model. Some of our data are still being analyzed, and many processes and parameters of the model still need refinement. Therefore, examples presented here are intended to illustrate the capability of the model rather than to represent our best or final predictions about the system. For this reason, initial inputs and parameters are described briefly without complete documentation.

Input Data

Total forage production (table 2) for all simulations described here is based upon data obtained from the largest allotment within the study area. Phenologies of plants were estimated from BLM records for the area, and caloric densities of forage species were obtained from sources in the literature, particularly Cook et al. (1977). Caloric densities ranged from 3.72 kcal/g for highly palatable grass species such as gramagrass during early growth to an arbitrary 1.0 kcal/g for unpalatable forbs that are not eaten.

Table 2. Forage production data used for simulation.[1]

Species	Kg/Ha
Grass and Grasslike Plants	
Wheatgrass (*Agropyron* sp.)	39.0
Fescue (*Festuca* sp.)	43.0
Ricegrass (*Oryzopsis* sp.)	1.0
Bluegrss (*Poa* sp.)	1.5
Needlegrass (*Stipa* sp.)	1.5
Junegrass (*Koeleria* sp.)	1.5
Other Cool Season Grasses	0.8
Gramagrass (*Bouteloua* sp.)	59.3
Muhly (*Muhlenbergia* sp.)	39.3
Squirreltail (*Sitanion* sp.)	22.8
Other Warm Season Grasses	0.8
Sedge (*Carex* sp.)	28.8
Rush (*Juncus* sp.)	0.5
Forbs	
Perennial Forbs - Unpalatable	64.5
Perrennial Forbs - Palatable	64.5
Annual Forbs - Unpalatable	64.5
Annual Forbs - Palatable	64.5
Browse	
Rabbitbrush (*Chrysothamnus* sp.)	137.3
Sagebrush (*Artemisia* sp.)	47.5
Cactus (*Cactaceae*)	8.0
Chenopods (*Chenopodiaceae*)	8.0
Yucca (*Yucca* sp.)	24.3
Mountainmahogany (*Cercocarpus* sp.)	1.3
Conifer	1.3
Other Browse	13.8
Total	838.5

[1]Based on data from Trickle Mountain, Colorado.

Initial numbers of wild ungulates were 300 bighorn sheep, 150 pronghorn antelope, 500 mule deer and 500 elk, unless specified otherwise. Sex and age structures were derived from Colorado Division of Wildlife estimates and body weights were obtained from the literature. Birth rates were based on the assumption that all female bighorn sheep age 3 and over produce 1 lamb per year, pronghorn age 2 years and over produce 2 kids per year, mule deer age 2 and over produce an average of 1.5 fawns per year, and elk age 2 and over produce 1 calf per year. Background death rates for animals under 1 year of age were 50% for bighorn sheep and pronghorn antelope, 40% for mule deer, and 30% for elk. A 10% annual death rate was used for all older animals of both sexes of all species. Harvest rates were derived from Colorado Division of Wildlife data and were 33% for adult male bighorn sheep over 2 years of age, 55% for adult male pronghorn antelope, 65% for adult male mule deer, 80% for adult male elk, and 10% for all other elk.

Seasonal forage preference values were derived from data on forage production and on food habits collected on Trickle Mountain and ranged from 0.01 for unpalatable forbs such as Hymenoxys (Hymenoxys sp.) to 20 for a highly palatable species such as mountainmahogany.

Forage production was assumed to be constant among years unless total use on a plant species exceeded an allowable use factor of 50%. When this allowable use was exceeded the forage production of that species was reduced in direct proportion to the degree of use beyond 50%, with a maximum reduction of 20% per year when utilization was 100%.

Simulation - Competition Between Wildlife

Wildlife managers often want to know if, or to what extent, a reduction in one wild ungulate would allow an increase in another species due to increased forage availability. To simulate such a situation we used an 8,000 ha area with all wildlife species present and systematically reduced the initial elk population to observe any effect on pronghorn antelope. A 50% reduction (250 animals) in the elk herd had a negligible effect (19 additional animals) on the antelope population, and a 75% reduction of elk (375 animals) produced only moderate increase in antelope (60 additional animals) at the end of 4 years (fig. 1).

Simulation - Competition Between Wildlife and Livestock

A common and controversial problem in forage allocation is predicting how livestock grazing practices will affect wild ungulate populations. To simulate this situation we used the same 8,000 ha area and systematically increased the intensity of summer-fall livestock grazing. Grazing resulted in lower densities of deer at all intensities and caused virtual extirpation of deer at the highest intensity (fig. 2).

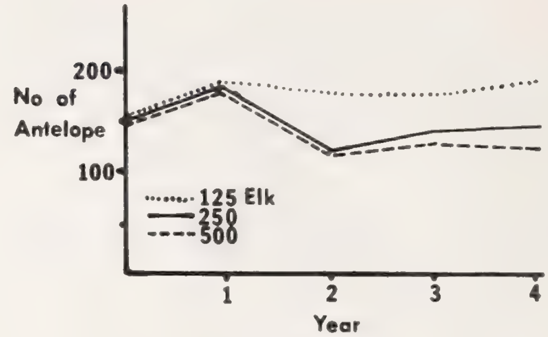

Figure 1. Simulated antelope populations with varying numbers of elk.

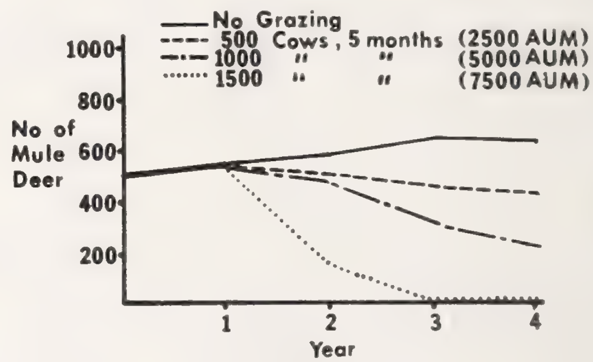

Figure 2. Simulated mule deer populations with alternative stocking rates of livestock.

Sensitivity Analysis - Forage Quality

Simulation models can also be used to increase our understanding of grazing land ecosystems to suggest fruitful areas for research, and to determine which data are most important in determining model outputs. Sensitivity analysis is a tool commonly used for such purposes. In sensitivity analyses one variable is sytematically altered while other parameters are held constant. In a sensitivity analysis, using the above parameters and initial populations for a 40,000 ha area with a 2,000 ha winter range, the caloric densities of forages was systematically changed. In successive simulations, the caloric densities were altered in increments of 0.1 kcal/g of digestible energy, going from -0.2 to +0.2 of the norms for all species at all phenological stages. Changes in simulated population levels for mule deer over 4 years were substantial with both increased and decreased caloric densities (fig. 3). This suggests that forage quality rather than

forage quantity is limiting the mule deer population.

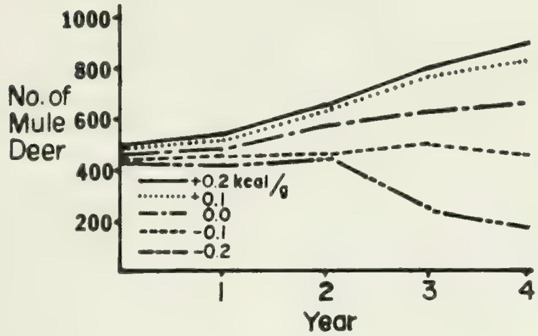

Figure 3. Simulated mule deer populations at varying caloric densities of available forage.

DISCUSSION

Much time and effort are being spent gathering quantitative data on forage production, food habits of wild and domestic animals and population densities of wild ungulates. Furthermore, much research effort has been and continues to be expended in quantifying such relationships as the effect of forage quality on animal health and reproduction, the effect of age structure on dynamics of wild populations, and the effect of grazing on population dynamics of plant species. Yet decisions regarding forage allocation are often subjective or based upon a qualitative evaluation of the above data, or they are based upon methods that utilize only a small fraction of the available data and of our knowledge of the grazing land system. Computer simulation provides an efficient method of integrating inventory data with basic biological data in order to assist resource managers in decision making.

The examples presented illustrate some types of "what if" questions that can be addressed by simulation models. Since forage and habitat preferences vary among ungulate species, decreasing numbers of one species may not result in a great increase in another. Allocation models based upon AUM equivalents cannot consider such phenomena.

The question of how wild ungulates respond to livestock grazing is a common problem. The above example with cattle and mule deer suggests that under the given initial conditions from the Trickle Mountain area livestock grazing will cause a decline in numbers of deer. However, other simulation runs using different data showed little effect by light and moderate livestock grazing on wild ungulate numbers. This indicates that generalizations such as "livestock grazing is good for deer" or "cattle grazing is detrimental to bighorn sheep" are of questionable value since the impact of 1 ungulate upon another will depend upon the numbers involved, seasons of use, the types of forage available and the weather conditions, at least. In short, such relationships are quite site- and weather-specific.

Sensitivity analysis as illustrated above can be a powerful tool for gaining understanding of the system under management. In the above example, mule deer responded directly to increases or decreases in forage quality. However, in the same analysis elk did not resond to variation in forage quality. This suggests that the current harvest rate might be limiting the elk population on Trickle Mountain. In an additional simulation, removing the antlerless harvest resulted in an increasing elk population.

Simulation models can thus be used not only to make quantitative predictions or testable hypotheses about effects of forage allocations, but also to gain understanding of factors limiting or controlling the numbers of plants and animals in the system. Thus simulation can be useful both in focusing research efforts on productive areas and also in efficient allocation of money and manpower among inventory, site-specific studies, and basic research.

SUMMARY

A computer simulation model has been developed to predict impacts upon ungulates of selective forage removal by free-ranging big game and domestic livestock. The model predicts forage removal from a set of habitat types as a function of the standing crops of forage, densities of big game and livestock, seasonal trends in animal distribution and forage preferences, weather patterns and previous forage removal. Predicted forage removal by ungulates is used to estimate trends in qualities of diets. Impacts upon weight changes, reproduction and mortality are predicted from diet qualities and nutritional requirements of animal species. The model was developed using data from a semiarid range in southern Colorado. The area is grazed year-round by bighorn sheep and pronghorn antelope and seasonally by mule deer, elk, cattle, and horses. Data on forage production and on food habits and distribution of all 6 species have been collected for 2 years. These data, with data on ungulate population levels, weather patterns and basic ungulate biology are integrated in the computer model. Computer simulation provides an efficient method of integrating inventory data with basic biological data in order to assist resource managers in decision making.

RESUMEN

Se desarrolló una simulación digital para predecir el impacto que tiene la remoción de forraje por fauna mayor y ganado doméstico sobre

sus mismas poblaciones. El modelo predice la remócion de forraje en un conjunto de varios tipos vegetativos como una función de la biomasa de forraje disponible, densidades de fauna mayor y ganado, tendencias estacionales en la distribución animal y sus preferencias alimenticias, factores climáticos y previa remoción de forraje. La predicción es utilizada para estimar tendencias en la calidad de la dieta. Combinando esta última información con los requerimientos nutricionales de cada especie, se predice el efecto sobre cambios de peso reproducción y mortalidad. El modelo fue desarrollado en base a información obtenida en una zona semidesértica en el Sur de Colorado. El área es pastoreada durante todo el año por borrego cimarrón y berrendo, y utilizada estacionalmente por venado bura, ciervo american, ganado vacuno y caballar. Se recabaron datos sobre producción forrajera y sobre hábitos alimenticios y distribución de las 6 especies en cuestión durante un periódo de 2 años. Estos datos son integrados con factores climáticos, niveles poblacionales y Biología básica de las 6 especies para así completar el modelo. La simulación provee un método eficiente para integrar datos inventariales con información biológica básica y así asistir a los especialistas en uso y manejo de recursos para elaborar decisiones de trabajo.

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Pinyon-Juniper Woodland Inventory[1]

Thomas R. Costello[2]

Abstract.--The Bureau of Land Management has a Forest Inventory Data Processing System as part of its Strategic Plan. This paper describes the development of the Pinyon-Juniper Woodland data processing system. It also describes the development of user guides for the implementation of the system.

INTRODUCTION

This paper describes the data processing system under development for the Pinyon-Juniper Woodland Inventory in the State of Nevada, which is in the Southwestern part of the United States of America. In a broad sense, it outlines the Bureau of Land Management's tree data processing system. The Bureau of Land Management is an agency of the United States Department of the Interior. It manages approximately 450 million acres of public land, 22 million acres are estimated to be in the State of Nevada. (BLM 1978). We will look at the data processing system in four parts: (1) User Requirement Documentation for Forest Inventory (BLM 1978a); (2) Important considerations in building a Forest Data processing system; (3) The Forestry Data Processing System; and (4) Tree Computation Program.

USER REQUIREMENT DOCUMENTATION

The final High Priority User Requirement Specifications for a forest inventory represents the first step in the design phase of the forest inventory; it is a summary of the user's requirements for forest resource inventory data.

The information in this paper is outlined as follows:

1. Introduction.
2. User Environment.
3. Forest Management Information Flow.
4. Probable Impacts of the Data Base.
5. Problem Areas and Recommendations.
6. Detailed Description of the Outputs.
7. Detailed Description of the Inputs.

This paper is a consensus of the comments received by the review teams from Oregon, Idaho, (340) and the Field Advisory Committee, February 15, 1978. It provides the basis for building the Forest Inventory Data Processing System.

The following summary of the assumptions were developed by the various teams as guides in building user requirement specifications. These needs were incorporated in the design of the Forest Inventory System as much as possible (BLM 1978a).

1. New data elements can be added, changed, or deleted as needed.

2. The "System" can be changed as needed.

3. "Standard" inputs and outputs can be changed as needed.

4. The system will have the capability to respond to "ad hoc" requests, that is, to provide reports, tables, charts, etc., in a simple-to-operate generalized retrieval capability.

5. There will be a terminal with graphic display at each district and/or resource area field office.

6. The system will be able to calculate acreage from map inputs and will be able to produce maps.

7. The system will be able to display overlays of various data themes and be able to calculate, sort, and summarize the results of the overlays.

BUILDING A DATA PROCESSING SYSTEM

The philosophy used in the design of the Forest Inventory System has been documented in "FORTRAN

[1]Paper presented at the Arid Land Resource Inventories: Developing Cost Efficient Methods. LaPaz, Mexico, November 30 - December 6, 1980.

[2]Thomas R. Costello, Natural Resource Specialist; United States Department of Interior, Bureau of Land Management, Denver Service Center, Denver Colorado.

PROGRAMMING CODING STANDARDS" (Wong 1980) which is summarized as follows:

Time-sharing programs will be written with the users convenience and ease of operation in mind. Figures 1 and 2 are illustrations of two time-sharing programs written in two different languages which demonstrate user convenience.

```
 FMRDB/TERMUP


NOV 25,1980 ; 9:23 PM
THIS IS PROGRAM TERMUP,MEMORY USED-11K.

 ENTER 2 CHARACTER STATE CODE

=NV



PLEASE CHOOSE FROM THE MAIN MENU:
1=BUILD UPDATE FILE.
2=WRITE CURRENT UPDATE FILE ONTO PERMANENT FILE.
3=STOP RUN.

=1

PLEASE CHOOSE THE FILE TYPE FOR UPDATING:
1=TREE.
2=SEGMENT.
3=STAND.

=1

PLEASE ENTER FORM NUMBER:
1=DSC 5250-3
2=DSC 5250-5
3-DSC 5215-1

=1

ENTER UPDATES AS EITHER REPEAT UPDATES OR SINGLE LINES.
SINGLE LINE FORMAT:SEQ. NO.,UP TO 4 ERR. NO=CORRECTIONS
REPEAT FORMAT:SEQ. NO. OF FIRST-SEQ NO. OF LAST,UP TO 4 CORRECTIONS
EXAMPLE OF SINGLE LINE: 21,E010=1345,E009-HA,E080=15
EXAMPLE OF REPEAT LINE: 2-189,E017=21456,E111=23
  NOTE THAT THE ABOVE EXAMPLES ARE FOR TREE OR STAND FILES,
  FOR SEGMENT FILES,ENTER ONLY TWO DIGITS AFTER THE 'E'
WHEN DONE,TYPE IN 'END'

=701-742,E109=59
=596-620,E109=59
=END

PLEASE CHOOSE FROM THE MAIN MENU:
1=BUILD UPDATE FILE.
2=WRITE CURRENT UPDATE FILE ONTO PERMANENT FILE.
3=STOP RUN.

=2
PLEASE ENTER THE COMPLETE UMC/CATALOG/FILE NAME
OF THE PERMANENT FILE YOU WISH THE UPDATES WRITTEN TO
AFTER YOU HAVE DONE SO,THE PROGRAM WILL LIST THE CATALOG
OF THAT FILE,THEN IT WILL ASK YOU WHETHER YOU STILL WANT
TO USE THAT FILE FOR THE UPDATES--IT WILL CONTINUE IN THIS LOOP
UNTIL YOU HAVE CHOSEN A FILE FOR THE UPDATES



=A135/NVTRUP02

REQUEST DENIED-CAT/FILE 'NVTRUP02' DOES NOT EXIST
DO YOU WISH TO USE FILE A135/NVTRUP02
FOR YOUR PERMANENT FILE(1=YES,0=NO)?

=1
COPIED 5 LLINKS


IF YOU WISH TO EDIT FILE A135/NVTRUP02
PLEASE REMEMBER TO USE CONV FILE-NAME TO FETCH IT AND
CONV FILE-NAME=FILE-NAME:BCD TO RETURN IT WHEN DONE EDITING



PLEASE CHOOSE FROM THE MAIN MENU:
1=BUILD UPDATE FILE.
2=WRITE CURRENT UPDATE FILE ONTO PERMANENT FILE.
3=STOP RUN.

=3

*
```

Figure 1.--The example of the terminal update program illustrates the ease of use. The user replies follow the "*" and the "=" symbols. The remaining material is printed by the program.

```
*A135/TR010
THIS PROGRAM BUILDS THE JOB CONTROL DECK WHICH

MAKES THE FILES SPACE FOR YOUR TREE AND SEGMENT

PROGRAMS

YOUR MAIL CODE.RESOURCE AREA AND NAME FOR BANNER ?

==NV040 SCHELL R. A. HARRY RHEA
YOUR DISK PACK IDENTIFICITION (5 character alpha-numeric(RPnnn) ?

==RP061
YOUR DISK PACK UMC ?

==A189
DISTRICT CODE IS THREE CHARACTERS - ALPHA

YOUR DISTRICT FILE CODE ?

==ELY
YOUR RESOURCE AREA - FIRST DIGIT ONLY ?

==0
PLEASE CHOOSE FROM THE MENU

T = TREE FILES

S = STAND FILES

YOUR FILE TYPE ?

==T
YOUR INVENTORY UNIT NUMBER ( 3 DIGIT NUMBER) ?

==888
YOUR TREE FILE SIZE NEEDED IN LLINKS ?

==2000
YOUR SEGMENT FILE SIZE NEEDID IN LLINKS ?

==400
THE NUMBER OF TREE RECORDS MUST BE EIGHT DIGITS

EXAMPLE:4000 RECORDS WOULD BE INPUTTED AS 00004000

WHAT IS THE NUMBER OF RECORDS ?

==00005000
00005000 ENTERED
8 DIGITS FOUND
THE NUMBER OF RECORDS MUST BE EIGHT DIGITS

EXAMPLE:4000 RECORDS WOULD BE INPUTTED AS 00004000

WHAT IS THE NUMBER OF SEGMENT RECORDS ?

==00002000
00002000 ENTERED
8 DIGITS FOUND
```

Figure 2.--This example of a use of the "TEX" subsystem asking the questions necessary to build a Job Control Language Deck for the users. The responses to the questions follow the "==" signs. The remaining material is printed by the program.

For traceability, each record of raw input shall have a unique identification. This identification will be passed along as a parameter to all sub-routines. This will allow us to trace problems within the programs easily.

A system-wide debug option will be built into each sub-routine and will be activated at the users request. ERROR MESSAGES generated by the program shall be clear and understandable.

In summary, the design philosophy is to make the operation and understanding of the forestry programs as easy as possible for the user and to provide program documentation as clear as possible for future maintenance - assuming the maintainer is going to be a junior programmer.

In building the system, the following documents are available to aid the user. The first is the Data Element Dictionary. This contains all the valid codes and definitions for each data element. This dictionary is being shared with other agencies in an attempt to provide common nomenclature for data collection. In forestry, the dictionary has been sub-divided into several sections as shown in Table 1.

Table 1.

Application Number	Name	Number of Elements
0151	Forestry	654
0152	TREE MASTER	86
0153	STAND MASTER	78
0154	Photo-Map Master	77
0155	TREE computation	73

The first item listed, Forestry, contains a general listing of all elements related to forestry. The next four items in Table 1 are specific subsets of the main dictionary with the tree data being divided into two groups.

OPERATING INSTRUCTIONS

Instructions for executing the programs is the next major set of documents available to the user. These sets of directions complement and further clarify the proper usage of programs, such as "A135/010", see Figure 2 for an example of the questions and responses.

FOREST DATA PROCESSING SYSTEM

The Forest Inventory System has been divided into three major information types: Tree, Stand, and Photo-map data. This discussion will be restructed to tree information. But first, a few comments on the origin of this inventory project. Early in 1977, the Forestry Staff at the Bureau's

Denver Service Center, received a request for assistance to determine the Pinyon-Juniper resources in the Ely District. Soon this project became a cooperative effort with the Resource Evaluation Unit of the Intermountain Forest and Range Experiment Station at Ogden, Utah, with the photo-map data being gathered by the State of Nevada. The project changed from an inventory for the Ely District to one covering all the Bureau's lands within the State of Nevada. It is estimated that there are somewhere between 6 to 17 million acres (2.3 to 6.7 million Hectors) of Pinyon-Juniper Woodland in the State of Nevada.

Data processing was begun using the data collected on Bureau of Land Management's forest inventory forms and is now being changed to forms developed by the Resource Evaluation Unit in Ogden, Utah, in an effort to have a more standarized data collection system between the two agencies.

The tree measurement forms will go through the following steps to assure that data has been accurately recorded. There is a thorough check made by the inventory crew using the field data collection procedure handbook as a guide. The forms are checked for completeness and correctness. This step is completed before leaving the field plot. The next check is made in the office by the field supervisor. Then the forms are sent to key entry at the Denver Service Center. Here they are entered into a standard file format for use by TREE EDIT/UPDATE PROGRAMS.

The completion of keying marks the first time the user is involved in computer processing. His first action will be to copy this data file into his USER MASTER CATALOG. Next, he will use a time-sharing program to build the file space required for the EDIT/UPDATE PROGRAMS.

To do this, he will execute the program called "A135/TR010". This program will provide a dialogue, that is, a question/answer routine which collects the necessary data to build the job control language deck. Figure 1 is the dialogue for building the job control language which executes the programs, and then builds the file space and address on the random file for the tree data.

A similar time-sharing program is executed to build the job control language control deck to run the EDIT/UPDATE PROGRAMS. The time-sharing approach relieves the user from getting involved directly with the complicated job control language and eases his communication with the computer.

Presently, the EDIT/UPDATE procedure for Tree Data consists of two programs. The first is PD205. This program takes the incoming data as recorded by the field crews, then it loads the data, then checks all the coded items against the Data Element Dictionary for validity. Next, it generates a printout of the errors found. This program also checks for duplications and in the case of more than eight errors, the entire record is rejected and must be corrected and re-entered.

The program also updates the files; the updating will be discussed in more detail later. This first edit is a general one. Next is a detailed edit which may be tailored to the specific inventory area. For example: Data Element 6100, Tree Species, contains 320 species; only eleven are found in the State of Nevada. These eleven species are then verified using FINSYS-2-SUB-SYSTEM-EDIT-2 (1978 Barnard).

This Forest Service program has been adopted by the Bureau to aid in the editing of our inventory data. One advantage of EDIT-2 is that it allows the user to tailor the edit to meet local conditions, while PD205 is EDIT set up to make validity check data from the eleven western states of the United States of America. We are using a broad general edit in conjunction with a specific edit.

At the end of each of our edit runs, an error list and dictionary is generated. Each error has been assigned a number which is referenced in the dictionary as shown in the example. The error number, along with the sequence number, which is assigned by the edit program, is used to update the data file. Figure 3 is an example of a portion of the error and tree dictionary listing.

The next step is to correct all errors on the TREE DATA master file. To do this, we build a correction file which consists of the following information:

1. SEQUENCE NUMBER - This number provides the address on the file (Identification) of the record to be corrected.

2. STATE CODE - This identifies the state where the correction originated.

3. ERROR NUMBER - This tells which field on the record are found in the file.

The building of the update file can be accomplished in one of two methods. The first is by use of an interactive program called "TERMUP" which is short for terminal update. Second, in areas where a terminal is not available, the changes will be coded on the Form (DSC 5250-6) or the tree error list, then these forms will be returned to key entry.

Figure 2 is an illustration of the use of "TERMUP" to build the update file.

Following update program execution, the results are generally available to the forester, within an hour or less, depending on the number of other jobs in the computer.

Upon completion, or during the edit phase, the forester can also list the data that has been

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TREE ERROR LIST

SEQ NO.	DIST	PU	STAND	TRANS	PLOT	TREE	ELEMENTS IN ERROR						
00000722	03	06				572	E058=	E050=	E054=	E061=	E062=	E109=	E011=
00000723	03	06				573	E058=	E050=	E054=	E061=	E062=	E109=	E011=
00000724	03	06				574	E058=	E050=	E054=	E061=	E062=	E109=	E011=
00000726	03	06				577	E058=	E050=	E054=	E061=	E062=	E109=	E011=
00000727	03	06				578	E058=	E050=	E054=	E061=	E062=	E109=	E011=
00000728	03	06				579	E058=	E050=	E054=	E061=	E062=	E109=	E011=

Figure 3a.--The Tree ERROR List is a portion of the results of executing the EDIT/UPDATE program. The program adds the sequence numbers to the incoming record.

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TREE DICTIONARY LISTING

ERROR	DATA ELEM #	PICTURE	ERROR	DATA ELEM #	PICTURE	ERROR	DATA ELEM #	PICTURE
E#001= STATE ADM NO.	0004	9(2)	E#054= LAND FORM	5132	X(3)	E#107= LOG4 DEFECT	6130	9(2)
E#002= DISTRICT	0003	9(2)	E#055= AVG. STAND HGT.	5799	9(3)	E#108= LOG4 DED	6131	9(2)
E#003= RESOURCE AREA	0003	9(2)	E#056= PHOTO VEGETATION	2706	X(4)	E#109= TREE OR CVR CLASS	6125	9(2)
E#004= PLANNING UNIT	0003	9(2)	E#057= LAND USE PI	6101	X(2)	E#110= TREE CLASS (USFS)	5500	9(3)
E#005= SUB UNIT	5707	9(4)	E#058= TREE PLOT TYPE	5124	9(1)	E#111= ADD SEED SAPS	5502	9(2)
E#006= STAND OR SWA	****	X(4)	E#059= TREE AZIMUTH	3515	9(3)	E#112= SITE INDEX TYPE	5927	9(2)
E#007= NEW SYU OR INV UT	****	9(3)	E#060= TREE DISTANCE	6112	9(3)	E#113= SITE INDEX	6136	9(3)
E#008= NEW PLOT NO.	6110	9(4)	E#061= TREE HISTORY	6115	9(2)	E#114= TWIG INTERSECT	5486	9(2)
E#009= TRANSECT NO.	3508	9(2)	E#062= TREE SPECIES CD.	6100	X(3)	E#115= BRANCH INTERSECT	5487	9(2)
E#010= TREE POINT NO.	3512	9(3)	E#063= TREE SCI. NAME	2246	X(6)	E#116= FIRST DUFF	5488	9(3)
E#011= TREE NO.	6114	9(3)	E#064= NO. OF TREES	6189	9(2)	E#117= SECOND DUFF	5489	9(3)
E#012= HISTORICAL	5496	9(1)	E#065= PAST DBH	6116	9(4)	E#118= SOUND 3 INCHES	5490	9(2)
E#013= STATE GEO. CODE	0002	X(2)	E#066= PRESENT DBH	6116	9(4)	E#119= ROTTEN 3 INCHES-1	5498	9(2)
E#014= STATE GEO. NO.	0004	9(2)	E#067= DSH	6008	9(4)	E#120= FUEL SLOPE	5493	9(1)
E#015= COUNTY CODE	0002	X(3)	E#068= DCH	6191	9(4)	E#121= LOGGED	5503	9(1)
E#016= STATE ADM. CODE	0002	X(2)	E#069= 10YR RADIAL GRTH.	6117	9(3)	E#122= MANAGEMENT TREE	5504	9(1)
E#017= ALLOTMENT	0968	9(4)	E#070= BARK THICKNESS	6135	9(3)	E#123= DOWN TREE	5506	9(1)
E#018= RANGE SITE NO.	3528	X(10)	E#071= TREE AGE BH	6134	9(2)	E#124= FOREST MGT. RX1	5835	9(3)
E#019= MASTER UNIT	5891	9(2)	E#072= AGE TO BH	6128	9(2)	E#125= FOREST MGT. RX2	5835	9(3)
E#020= OLD PLOT NO.	6110	9(4)	E#073= TOTAL AGE	6138	9(4)	E#126= ACRES	6520	9(4)

Figure 3b.--This Tree Dictionary provides the user with a cross reference to what each error number means.

entered into the system. This will provide him with a hard copy of his data.

Comments on our prorams - the EDIT/UPDATE and the computation programs are, or will be, batch execution. That is, once launched, the execution is controlled by the computer. This is in contrast to interactive processing during which each unit of information is processed immediately at the time of terminal entry. For example, the "TERMUP" program is an interactive program.

COMPUTATION PROGRAM

The next major step in our efforts will be the building of the tree computation program. The following is a summary of the features of the program.

Selection of Input Option Routine

This selection will allow the user to use a standard or stranger input file.[3] He will also select the volume, form class and other equations needed to process the inventory. This program will also do limited editing, checking and build a disk file which may be stored and used to execute future runs of similar data. Such a file facilitates batch execution.

The Bureau has elected to build the control deck in this manner to make it easy for the human operators. Control decks have been the major source of errors and delays in operating batch programs. We hope by the use of the inactive routine to cut down the number of syntax errors and thereby increase the number of meaningful batch runs.

Verification Routine

The verification routine will edit the control deck built during the selection of input optim. This program will also check the input file for correct format. In the case of errors or omissions, the user will be notified. If the error is of a type that would cause the program to run erroneously or to fail, this subroutine will abort the run in a controlled manner.

Computation Routine

The computation program will do all the computation and generate the data on a fixed format file. This output file may then become the input data for statistical program and/or a specific or general data reduction program or a data stranger and retrieval facility such as the statistical package for the Social Sciences FINSYS-2 or REX.

Output Routine

The output routine program will generate standard printed outputs on request. It will allow the user to define which table he wishs to see. The basic set of tables will include individual tree and plot volume stand and stock tables and summary tables where applicable.

[3]Stranger files are those which contain at least the required variables but not in the standard format.

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RESUMEN

El Negociado de Manejo de Tierras mantiene un Sistema de Procesamiento de Data para Inventario Forestal como parte de su Plan Estratégico. Este artículo describe el desarrollo del sistema para procesamiento de la data sobre el junípero Piñón. También se describe el desarrollo de guías para uso en la implementación del sistema.

Assessing Arid Rangeland Hydrologic Resources[1]

Gary W. Frasier, Kenneth G. Renard, and J. Roger Simanton[2]

Abstract.--One approach for evaluating the consequences of various land management practices is to use computer models which are verified on selected highly instrumented representative areas. The input variables to the models are varied and the effect of the changes observed. Models discussed include precipitation, runoff, and erosion processes.

INTRODUCTION

The arid rangelands of the world have a past history of land misuse coupled with low precipitation and a general low soil fertility. These lands represent a sizeable portion of many countries, and with proper management techniques, can provide significant quantities of food and fiber. With the fragile ecological balance of these areas, inappropriate range management techniques can cause irreversible damage to soil resources which are often critically limiting. The present relatively low economic value of these lands precludes extensive onsite assessment or field-scale testing of the multitude of alternate uses or management practices for their potential effects on the hydrologic resources.

Computer simulation is a technique which permits a rapid evaluation of various proposed land management practices. Models are developed and verified from data collected on selected highly instrumented representative areas. With the models verified, the input variables representing proposed range improvement or management practices are selectively varied and the hydrologic effects of the changes observed. Hydrologic models range from relatively simple statistical approaches to highly complex mathematical relations. The success of any model for predicting the effects of management practices depends upon the validity of the basic concepts and the ability of the model to describe conditions at ungaged sites. Following is a limited discussion of some of the models used for representing precipitation variations, surface runoff, and soil losses by water erosion.

PRECIPITATION

The limited rainfall in arid lands is a result of many complex atmospheric processes. As a result, the rainfall over a given area is extremely variable in quantity and intensity, both in time and space. An accurate physically based model of rainfall processes is not presently available. Thus, statistical models developed from historical precipitation records are used most frequently (Renard and Brakensiek, 1975).

Probability Model

In many places of the world, it has been shown that a simple Markov chain probability model can be used to indicate the frequency distribution of rainfall events (Caskey, 1963; Feyerherm and Bark, 1965; Gabriel and Neumann, 1962; Hershfield, 1970; and Woolhiser et al., 1972). This model assumes that the probability of rain occurring on a given day is only a function of the occurrence or nonoccurrence of rain on the previous day.

Smith and Schreiber (1973, 1974) were able to show that these simple Markov chain models could describe the probabilities of the number of wet days in the summer thunderstorm season (June through September) in southeastern Arizona (fig. 1), and the total summer rainfall (fig. 2). This type of information is useful for the selection of range plants which might have specific moisture requirements during the growing season.

By considering storms of sizes above some required threshold level, Smith (1974) showed it was possible to estimate the frequency of storm events of various sizes. Probability models, while relatively simple, do have the disadvantage of not being able to anticipate on a yearly basis the extreme events or periods caused by short term climatic fluctuations.

[1]Paper presented at Arid Land Resources Inventories: Developing Cost-Efficient Methods, La Paz, Mexico, November 30 - December 6, 1980.

[2]Gary W. Frasier and Kenneth G. Renard are Research Hydraulic Engineers, and J. Roger Simanton is a Hydrologist at the Southwest Rangeland Watershed Research Center, U.S. Department of Agriculture, Science and Education Administration, Agricultural Research, Tucson, Arizona 85705.

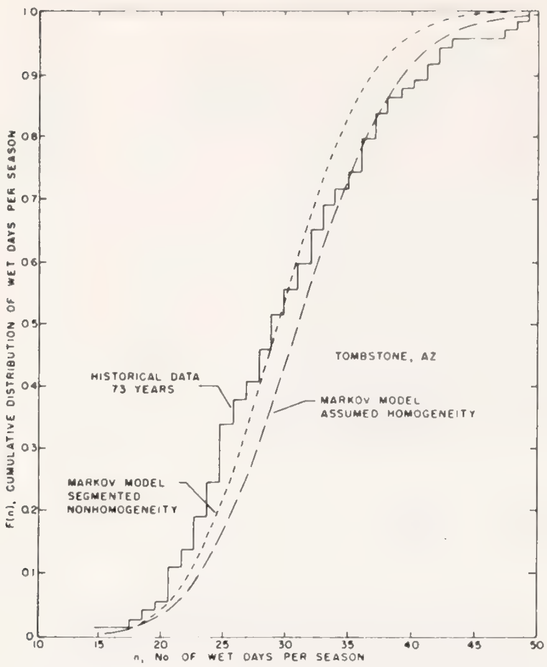

Figure 1.--Predicted and observed cumulative distribution of the number of wet days per season at Tombstone, Arizona (from Smith and Schreiber, 1973).

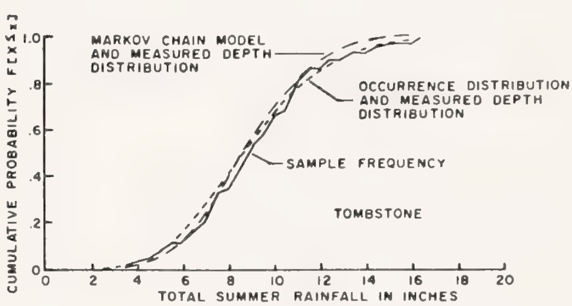

Figure 2.--Measured and simulated distribution of total summer seasonal rainfall at Tombstone, Arizona (from Smith and Schreiber, 1974).

Simulation Model

In many areas, it may be desirable to extend point rainfall data to larger areas and predict the areal distribution of rainfall quantities or intensities. Osborn et al. (1980) developed a computer model for simulating rainfall occurrence and amount on ungaged watersheds in Arizona and New Mexico up to 58 mi^2 in size with elevations between 1000 and 7500 feet. The model was developed using available rainfall records from USDA, Science and Education Administration (SEA) experimental watersheds and the National Weather Service raingage network in Arizona and New Mexico. This model can generate rainfall input data for use on ungaged areas (within the model verification area) where actual precipitation data are limited. Model testing has shown that it reproduces storm characteristics for both airmass and frontal-convective thunderstorms.

Figure 3 shows a storm event on the Walnut Gulch Experimental Watershed in southeastern Arizona. The rainfall model can simulate this type of storm and estimate point rainfall for any location within the subwatershed or a total volume across the entire area. This model can also simulate storm cell movement across the watershed and multiple storm events within a 24-hour period.

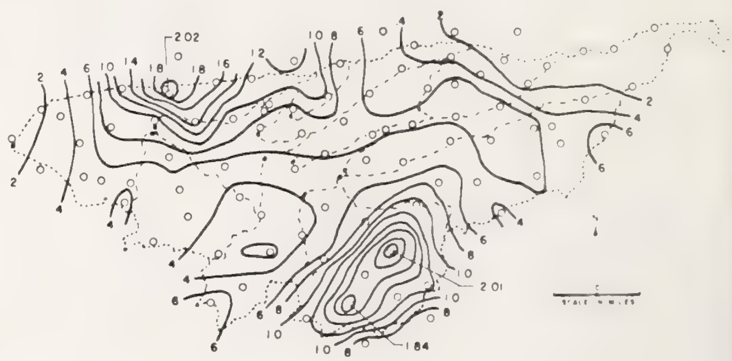

Figure 3.--Isohyetal map of the 31 August 1968 storm on a Walnut Gulch watershed.

Simulation models are useful tools but have a disadvantage of requiring relatively large computer capacities. With the simulation programs, it is possible to determine probability distribution functions of point rainfall or isohyetal projections of seasonal or annual precipitation.

RUNOFF

Runoff prediction procedures for a given amount of rainfall have ranged from simple to rather difficult and complicated techniques (Renard, 1977). Procedures used at the Southwest Rangeland Watershed Research Center include the SCS curve number method and the more involved nonlinear kinematic runoff models where an infiltration equation is used to estimate precipitation excess, and this runoff is then routed over planes to channels (Lane et al., 1978).

SCS Curve Number

The U.S. Department of Agriculture, Soil Conservation Service (SCS) has developed a runoff-predicting model (curve number) based not only on rainfall amounts, but also on watershed characteristics such as soil-cover complexes and antecedent moisture conditions. The hydrologic soil groups are divided into four classes based on infiltration and soil water movement characteristics. The cover groups are determined by land use and treatment classes. Land use varies from row crops to

dirt roads with most of the divisions associated with various agricultural uses. Treatment classes consist of straight row cropping, contouring, and terracing. The land use and treatment of an area are further divided into three hydrologic conditions--poor, fair, or good. Knowing these watershed characteristics, one can, by using tables and graphs provided in the SCS Hydrology Handbook (USDA, SCS, 1971), determine a watershed runoff curve number (CN). From this curve number, the watershed runoff can be determined for a given rainfall amount. The runoff from the curve number procedure can be computed by the following equations

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \quad (1)$$

$$CN = \frac{1000}{10 + S} \quad (2)$$

where Q is the runoff in inches, P is the rainfall in inches, and S is the potential maximum retention.

However, when the curve number method was applied to small plots on a semiarid rangeland watershed of southeastern Arizona, the runoff predicted using handbook curve numbers underestimated actual runoff (Simanton et al., 1973) (table 1).

Table 1.--Runoff curve numbers developed for Wal-Walnut Gulch plots[1].

Plot group	Land use	Table derived curve number[2]	Data derived curve number[3]
Kendall (grass)	Ungrazed	79	93
Kendall (grass)	Lightly grazed	79	94
Lucky Hills (brush)	Ungrazed	87	91
Lamb's Draw (brush)	Grazed	81	86

[1]6- x 12-ft plots.

[2]From tables in Hydrology Handbook (USDA, SCS, 1971).

[3]Actual rainfall-runoff data fitted to the curve number equation using the technique of least squared deviations.

The differences between the estimated and actual curve numbers from the plots were attributed to high rainfall intensity, absence of drainage networks, and the impact of small differences in antecedent soil moisture. In other climatic regimes, when rainfall intensity does not dominate the input to the hydrologic response of a watershed, the curve number model can be very useful in estimating runoff differences resulting from watershed treatments.

Partial Area Runoff

Hydrologists and engineers in the past have generally considered that runoff for a particular precipitation event was produced uniformly from the contributing watershed. Such assumptions were required because of the complexity of the processes and difficulty in solving equations to describe such processes. An assumption of uniform runoff may be adequate only when very small areas (i.e., < 1 acre) are involved or when the watershed is relatively homogeneous. This assumption is poor in arid and semiarid areas where the spatial variability of precipitation is dramatic (e.g., where air-mass thunderstorms are prevalent) and where the heterogeneity of the watershed is great. Recent investigations by Hewlett and Troendle (1975) and Lane et al. (1978) have illustrated the inadequacy of this assumption. The importance of partial area runoff knowledge is most significant in water quality programs.

When large watersheds are involved, the runoff from small watersheds must be routed to downstream points using the runoff estimates from small watersheds and the hydraulic conditions of the channel systems involved. In many ephemeral streams, runoff losses due to infiltration in the dry streambed can drastically alter the hydrograph shape and runoff volume (Renard, 1977).

EROSION

Erosion models can be very useful in estimating the soil resource loss or conservation associated with different management or cultural practices.

Universal Soil Loss Equation

One model widely used throughout the United States and other parts of the world is the Universal Soil Loss Equation (USLE). The USLE, developed by Wischmeier and Smith (1978), is intended to estimate the long-term average annual soil loss from agricultural fields. The equation is

$$A = R\ K\ L\ S\ C\ P \quad (3)$$

where A is the estimated soil loss in tons/acre/yr, R is the rainfall erosivity factor, K is the soil erodibility factor, L is the slope length factor, S is the slope gradient factor, C is the cover and management factor, and P is the erosion control management factor. These factors reflect the major variables which influence erosion by rainfall and resultant overland flow. The equation is based on plot data collected from areas east of the 105th meridian in the United States. Although it is intended for use beyond the area it was developed for, special considerations are required for it to be successful in other areas (Brooks, 1976; and McCool et al., 1976).

The parameters needed to evaluate each

Table 2.--Annual soil loss (tons/acre) from three small Walnut Gulch subwatersheds

Year		Brushland				Grassland		
	R[1] factor	No. 103 (9.1 ac)[2]		No. 104 (11.2 ac)		R factor	No. 112 (4.6 ac)	
		Predicted	Actual	Predicted	Actual		Predicted	Actual
1973	64	0.29	1.24	0.25	0.35	22	0.06	0.00
1974	79	0.36	2.17	0.30	0.75	77	0.22	0.01
1975	185	0.85	3.83	0.72	1.42	53	0.15	0.05
1976	30	0.14	1.08	0.12	0.31	114	0.33	0.37
1977	82	0.37	3.04	0.32	1.33	54	0.15	0.05
1978	45	0.21	0.89	0.17	0.08	25	0.07	0.00
1979	25	0.11	0.21	0.10	0.00	26	0.07	0.00
Avg.	73	0.33	1.78	0.28	0.61	53	0.15	0.07

[1]R = Hundreds of foot-ton inch per acre hour year.
[2]The watershed has an incised drainage network that contributed considerable soil loss.

equation factor are easily determined from handbooks and a minimum amount of field work. Factor values can be adjusted for local conditions, and a fair estimate of erosion can be made. Simanton et al. (1980) applied the USLE to three small watersheds in southeastern Arizona. Comparison of predicted and measured soil loss are presented in table 2.

In general, the USLE seemed to overpredict soil loss for years with small runoff events and underpredict soil loss for years with large runoff events. The USLE can be used to estimate the impact on soil loss rates caused by changing management or cultural treatments. By adjusting the factors to reflect estimated changes in K, C, or P, a fair estimate of potential soil loss can be obtained for the proposed management or treatment.

An example of such an application is taken from a study conducted on a 110-acre watershed in southeastern Arizona. This subwatershed of the Walnut Gulch experimental watershed was root-plowed and seeded in 1971 (Simanton et al., 1977). To help quantify soil loss changes associated with the treatment, the USLE parameters were evaluated for the pre- and post-treatment periods. Parameter values, soil loss prediction, and measured soil losses are presented in table 3.

The soil erodibility (K), cover (C), and erosion practice (P) were the parameters changed by the treatment. The changes in K and C were expected because of the disturbance of the soil surface and plant cover. The change in P was due to the root plowing treatment which resembled a contour listing treatment for which a parameter value of 0.15 is used. The small difference between predicted and measured soil loss indicates the usefulness of the USLE for estimating erosion consequences of different range management programs.

Sediment Yield Equation

The sediment yield of a watershed is the summation of the erosion from all sources within the watershed, including erosion from channel beds and banks, headcuts, etc., minus the deposition of sediment between the erosion sources and the watershed outlet. Deposition generally occurs when there is insufficient energy to transport the eroded sediments such as occur when land slope decreases, roughness increases, or as a result of man's activities which are intended to create deposition such as bank protection, grade stabilization structures, debris or detention basins, and water storage reservoirs. Thus, estimating sediment yield from areas larger than a few acres is a

Table 3.--USLE and soil loss from a small experimental watershed converted from brush to grass cover

Condition	USLE factors					Soil Loss	
	R	K	C	SL	P	Predicted	Measured
	(Avg)					(tons/ac/yr)	(tons/ac/yr)
Brush (1966-1970)	88	0.20	0.08	0.90	1.0	1.27	1.67
Grass (1974-1976)	47	0.16	0.15	0.90	0.15	0.15	0.13

very complicated problem requiring knowledge of both the runoff rate and amount and the ability to assess the erosion and deposition under a wide variety of conditions within the basin.

Physically based models to predict the many cause-effect relationships within the basin have, in the past, received only limited attention. There are, however, a variety of empirical equations which are site specific or have had limited testing beyond the area for which they were developed. Thus, these relationships required from the user a great deal of familiarity with the method and the area for which the estimates were required. As such, the practicing sedimentationist might more correctly be classified as an artist in his trade.

Renard (1980) used four sediment yield relationships to compare predicted and measured yield on nine small watersheds on the Walnut Gulch experimental watershed. Of the four empirical equations used (Flaxman, 1972; Dendy and Bolton, 1976; PSIAC, 1968; and Renard, 1972), the method developed by a subcommittee of the Pacific Southwest Interagency Committee (PSIAC) appears to give the best results (table 4). Furthermore, this method, which uses nine parameters, can readily be used to evaluate changing land use or conservation practices on sediment yield. In the other methods, indirect reflections of changing land use can be made by projecting changes in runoff or other parameters which are used to arrive at the estimate. In all the methods tested, quantification of the changes associated with land use are truly subjective, and thus, would be classified as an art.

Within USDA's Science and Education Administration, a group of scientists and engineers are developing models to assess nonpoint pollution from both field-sized areas and from heterogeneous small watersheds. The effort for the field-sized areas has culminated in a model called CREAMS (Chemical, Runoff, Erosion, and Agricultural Management Systems (Knisel et al., 1980) which enables simulation of the hydrologic cycle with analytical routines to account for erosion/sediment yield and the chemicals used in agricultural areas. The computer program, although quite involved, can be used without calibration for predicting nonpoint pollution from many management systems using parameter values specified in the user manual. The companion effort for the basin-size areas is presently in progress.

SUMMARY

The water resource assessment for any watershed is especially difficult because of the many differences in the climatic, physiographic, and land uses affecting the resources. The situation is especially acute on most arid and semiarid rangelands because of a paucity of data. For this reason, land managers, environmentalists, and hydrologists are resorting to simulation techniques in which models calibrated on areas with available data are used to simulate the resources for unmeasured areas. Furthermore, if such calibrated computer models are physically based, the effects of alternate land uses or, for example, improved range management practices, can be evaluated with considerable confidence.

Precipitation, a highly variable quantity in most rangelands, can be simulated if some relationships are known for the distribution of wet and dry days, the distribution of storm depths, and the areal extent of individual storms. For example, Markov chain probability models have been widely used to simulate the distribution of wet/dry days and a mixed exponential distribution for rainfall depths at a point.

Table 4.--Measured and predicted sediment yield for select semiarid rangeland watersheds (Renard, 1980)

Location designation	Drainage area (ac)	Measured yield	Predicted yield (ac-ft/mi^2/yr) PSIAC	Dendy/Bolton	Flaxman	Renard
201 (brush)	109	0.49	0.29	0.83	-0.180	0.68
201 (grass)[1]	109	0.13	0.19			
207	274	0.11	0.18	0.73	0.049	0.61
208	228	0.13	0.16	0.75	0.313	0.62
212	842	0.11	0.30	0.62	0.142	0.53
213	394	0.09	0.18	0.69	0.375	0.58
214	372	0.37	0.38	0.70	0.154	0.59
215	87	0.70	0.42	0.85	0.249	0.69
216	208	0.51	0.28	0.76	0.341	0.63
223	108	0.30	0.29	0.83	0.085	0.68

[1]Converted from brush to grass cover in 1971.

Assessing the water resources of rangeland watersheds also requires estimating runoff. Again, much can be gained with models. The most widely used technique for such an assessment is the curve number method of USDA's Soil Conservation Service. The method involves using precipitation amounts and a technique for estimating the associated runoff for various soil/cover complexes. When used and correlated with actual data in southeastern Arizona, differences between predicted and actual runoff were attributed to storm characteristics and differences in the drainage networks. With increasing watershed size, additional losses of water in the stream channel require using increasingly complex methods such as hydraulic routing of water from upstream points. This operation can best be accomplished with computer models.

One of the most widely used soil erosion models is the Universal Soil Loss Equation (USLE). The model was developed to estimate the long-term average soil loss from agricultural fields in the eastern United States. Preliminary evaluation of the model on three small watersheds in southeastern Arizona showed an overprediction of soil loss for years of small runoff events and an underprediction for years with large runoff events. The USLE adequately predicted the soil loss resulting when a brush watershed was converted to grass. Sediment yield equations that include all sources within a watershed have received only limited attention because of the difficulty in assessing the erosion and deposition under the wide variety of topographic and soil conditions which occur in most basins. Of four equations evaluated, an empirical equation developed by the Pacific Southwest Interagency Committee best represented sediment yield from 9 small watersheds in southeastern Arizona.

Efforts on developing prediction models for assessing nonpoint pollution for both field-sized areas and heterogeneous small watersheds are being undertaken by a group of scientists and engineers in the USDA's Science and Education Administration. This model is designed to be used without calibration for evaluating the effects of management systems on nonpoint source pollution. Modeling techniques represent a relatively inexpensive tool for assessing the present and future condition of our arid rangeland resources.

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EVALUACION DE RECURSOS HIDROLOGICOS DE TIERRAS ARIDAS

RESUMEN

La determinación de los recursos de agua para cual quiera cuenca hidrológica es especialmente dificil por la diferencia de clima, de topografía y de usos de la tierra que efectan los recursos. La situación es especialmente aguda en la mayor parte de los pastos áridos y semiáridos por los datos limitados. Por esta razón, gerentes de la tierra, personas interesadas en el ambiente, y hidrológicos están recurriendo al uso de técnicas de simulación con modelos que son calibrados para áreas con datos disponibles y son usados para simular los recursos de áreas sin medidas. Además, si la calibración de los modelos para uso en calculador son basados fisicamente, los efectos de usos alternativos de la tierra o, por ejemplo, el mejoramiento de las practicas de manejar los pastos se puede examinar con considerable confianza.

La precipitación, una cantidad muy variable en la mayor parte de pastos, se puede simular si se saben unas relaciones como la distribución de la cantidad de lluvia y la extención de lluvia. Por ejemplo, los modelos de Markov de cadena de probabilidad an sido usados extensiblemente para simular la distribución de días con lluvia y sin lluvia y para distribución exponencial mesclada para el nivel de la lluvia en un punto.

Para examinar los recursos de agua de los pastos de la cuenca hidrológica se requerir estimar el escurrimiento. En esto tambien pueden ayudar los modelos. La técnica usada mas para estas determinaciones es el métado de numeros de curba utilizada por el Servício de Conservación de Suelos del Departamento de Agricultura de los Estados Unidos (USDA Soil Conservation Service). El métado usa la cantidad de lluvia y la técnica para estimar el escurrimiento asociado con varios complejos de suelos y cubertura. Cuando se usa y se correlaciona con datos del sudeste de Arizona, diferencias entre la predicción y lo actual se atribullen a los característicos y las diferencias en el sistema de drenaje de la cuenca hidrológica. La determinación de la agua adicional que se pierde en los arroyos requierre el uso de métados mas complejos como el derrotero matemático de la agua por los arroyos. Esta operación se puede mas bien cumplir con modelos usando calculador.

Unos de los modelos mas usados de erosión de suelos es la ecuación universal de perdición de suelos (Universal Soil Loss Equation - USLE). El modelo se desarrollo para estimar el promedio de término largo de perdición de suelo de sembrados en el este de los Estados Unidos. El ensay preliminario de este modelo útilizo tres pequeñas cuencas hidrológicas en el sudeste de Arizona y resultó en una alta predicción de suelos perdidos para años con pequeños escurrimientos y en una baja predicción para años con grandes escurrimientos. La USLE adecuadamente predico el suelo que se pierde cuando una cuenca hidrológica cubierta con arbustivos se fue convertida a una cubierta con zacate. La ecuación de producción de sedimento que abraza todas las fuentes entre una cuenca hidrológica a recibido solamente poca atención por la dificultad de determinar la erosión y la disposición por la grande variabilidad de condiciones topograficas y de suelos que ocurren en la major parte de las cuencas. De las cuatro ecuaciones examinadas, una ecuación empirica desarrollada por el Comite Interagencia Pacífico Sudoeste (Pacific Southwest Interagency Committee) represento mejor producción de sedimento de nueve pequeñas cuencas hidrológicas en el sudeste de Arizona.

Esfuerzas para el desarrollo de modelos para áreas del tamaño de sembrados y pequeñas cuencas hidrológicas heterogeneas se a emprendido por un grupo de científicos y ingenieros de la Administracion de Ciencia y Educacion del Departamento de Agricultura de los Estados Unidos (USDA Science and Education Adminstration). Este modelo es designado para usarse sin calibración para examinar sistemas que manejan la fuente de contaminación sin punto. Técnicas de modelos representan un instrumento módico para determinar las condiciones presentes y futuras de nuestros recursos de pastos áridos.

TMIS - A Tool for Storing and Retrieving Resource Information[1]

Edward J. Gryczan[2]

Abstract.--The efficient storage and timely retrieval of natural resource information promotes efficient land and resource management. A system for storing and retrieving timber related information - TMIS is described. It is a system for storing inventory information and recording planned and accomplished management activities. The components of the system are portrayed and the operation and use of the system is described.

The Timber Management Information System (TMIS) is a structure and a procedure used by the U.S. Forest Service to store and retrieve timber related information using a series of interrelated data bases. Although the system described herein relates to timber land and timber resources, the system can be adapted to store and retrieve information about arid lands and their resources. The arrangement of the data bases, their internal relationships and the data elements stored, can be adapted to meet the specific information needs about arid lands.

TMIS is organized into three levels; Forest-wide, Region-wide and Service-wide (fig.1). In the Forest-wide level are the EXTENSIVE, STAND, PROGRAM, NURSERY, SALES, and TIMBER SALE ACCOUNTING data bases. Currently, there is only one data base at the Region-wide level; the TIMBER INVENTORY ADJUSTMENT data base. The Service-wide level consists of six data bases; TIMBER LAND USE CLASSIFICATION, SPECIAL UNIT, ANNUAL POTENTIAL YIELD, ANNUAL PROGRAMED HARVEST, SILVA, and HISTORY.

The design of the data base structure permits both horizontal and vertical integration. Program accomplishment information entered into the PROGRAM data base also updates the STAND data base. Data entered into the TIMBER INVENTORY ADJUSTMENT data base can be summarized and entered into the PROGRAMED HARVEST data base without additional data input by the user. This permits extraction of summarized data at the Service-wide level that was entered in more detail at a lower level data base.

There is some flexibility in the organization of the data bases, depending upon the volume of data and the amount of timber activity. In some Regions the EXTENSIVE data base is loaded and maintained at the Regional level. Some forests with voluminous STAND and PROGRAM data bases have delegated their operation and maintenance to Ranger Districts.

FOREST-WIDE LEVEL

The STAND and PROGRAM data bases are used in consort to maintain current records of inventory and management activities. STAND contains site specific information on the timber resource and other resources as they affect timber. A minimum data set is established nationally for STAND to permit aggregation of data for broader areas. Beyond these minimums, there is considerable flexibility to store data pertinent to local species and conditions.

PROGRAM contains the prescription and schedule of treatment activities. For each record in PROGRAM there is a parallel record in STAND. As each activity is completed, it is removed from the PROGRAM schedule and automatically entered into the historical portion of the STAND record. Thus, the STAND records are kept current without duplicate entries.

Records are stored in STAND for each timber stand examined. Therefore, it is not a complete inventory record of the entire forest until all stands are examined. The EXTENSIVE data base contains the complete record of the most recent extensive inventory. The information in this data base is used in the development of the Land and Resource Management Plan for each Forest. Summaries from the Forest data bases are aggregated to produce state and national inventory statistics.

The EXTENSIVE data base is only updated upon completion of a new extensive inventory, therefore, it is also used to develop trends in forest growth and condition.

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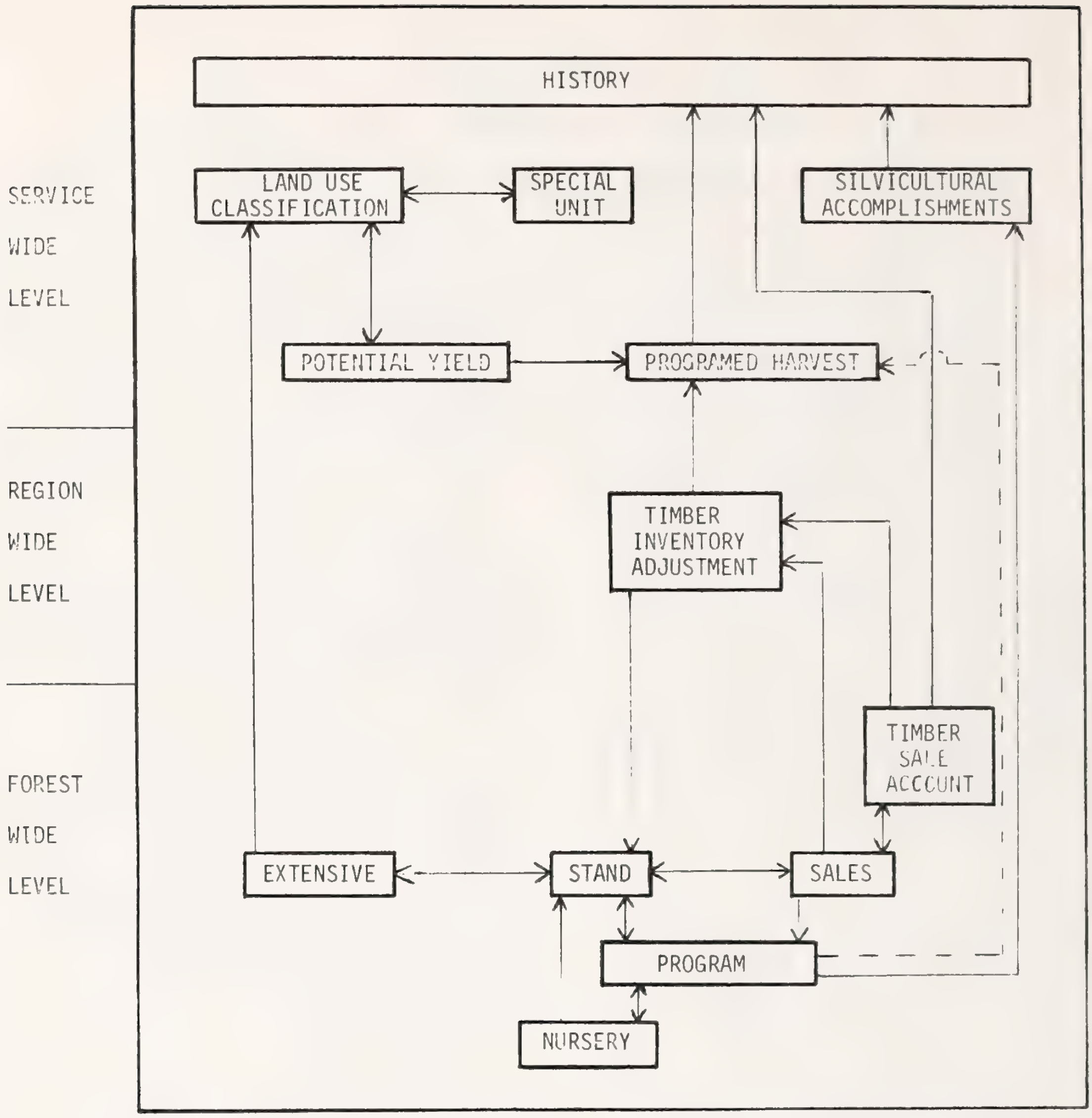

Figure 1.--Internal Relationships of the Timber Management Information System.

The NURSERY data base is designed to contain information about nursery operations such as seed inventories, viability tests, and seedling production. This data base is currently undergoing development and testing.

The TIMBER SALE ACCOUNT data base is also undergoing development. This data base will contain information on species and products, prices and volumes cut and sold.

The SALES data base has not yet been incorporated into TMIS, although a prototype is being used by one Forest Service Region. This data base contains the current five year timber sales program developed as part of the Forest Land and Resource Management Plan. This data base tracks the progress of individual timber sales from stand examination, through volume determination and harvesting, to establishment of regeneration. Because this process spans several years, it is an aid in developing future work programs and budget estimates.

REGION-WIDE LEVEL

There is only one data base at the Region-wide level. It is the TIMBER INVENTORY ADJUSTMENT data base. It is used to collect, store, and retrieve information about inventory drain, both from cultural activity and from natural causes. This information is summarized quarterly and passed to the PROGRAMED HARVEST STATEMENT data base at the Service-wide level.

SERVICE-WIDE LEVEL

This part of TMIS provides a national summary of lands available for management of the timber resource and the potential yield of wood products from these lands. It is the source of Regional and national summaries of timber management programs on the National Forest System and periodic accomplishment of these programs. It also provides a national summary of lands not currently available for management of the timber resource and the yield of wood products that could be available from these lands.

The LAND USE CLASSIFICATION data base is used to monitor changes in the management control land classes which comprise the Forests' total land base. Summaries are prepared periodically which show the area, volume, growth, and mortality for each land class. By comparison with previous reports, changes in areas and volumes can be identified as to extent and location.

The ANNUAL POTENTIAL YIELD (Allowable Harvest) expresses the total area and volume objectives for each National Forest as developed in the forest plan. It is a summary of the maximum possible annual harvest by the various components of that harvest such as land class, product, type group (hardwoods or softwoods) and harvest method. This data base also provides the basic information for the management control system used to summarize accomplishment in the Forest Land and Resource Management Plan.

The PROGRAMED HARVEST STATEMENT data base contains records about each Forests' budgeted timber sale program and accomplishment. This information is documented in terms of the components used in the calculation of the potential yield, such as the acres and volume programed for clearcutting and the acres and volume actually sold. This in turn forms the basis for recording progress towards accomplishment of the acreage and volume objectives established under the Land and Resource Management Plan. It is also the basis for the historical record of harvest accomplishments for each unit.

The SILVICULTURAL ACCOMPLISHMENT data base contains information about reforestation, timber stand improvement and compartment examination. This information is used to monitor accomplishment of these activities quarterly and provides information necessary for program attainment reporting.

The SPECIAL UNIT data base is identical to the LAND USE CLASSIFICATION data base except that it is limited to areas that are managed for special purposes, such as Wilderness, National Recreation Areas, and Geological Areas. This data base is used to monitor the extent of the areas and volumes that are not available for timber harvesting. Units proposed for special classification are also entered into this data base. Using the information in this data base, the affect of the proposed classification on the potential yield and programed harvest can be calculated or estimated for each unit.

The HISTORY data base is under development. It is being designed to accept information directly from the other Service-wide data bases, and provide a record of the amounts and kinds of cultural activities completed within each National Forest.

DATA EXTRACTION

The ease of data retrieval is one of the strong features of the Timber Management Information System. An integral part of the system is a reporting capability which permits extraction of periodic reports from each data base (fig.2). Producing these reports requires no computer programing skills. Only a few simple commands entered via a demand terminal are necessary.

The user has the option of modifying standard reports to meet his individual needs through the use of selected sort or extract commands (fig.3). The system can also be queried to obtain specific information without generating a report (fig.4).

DEVELOPMENT OF THE SYSTEM

Obviously, the development of an information system of this magnitude is not a short term undertaking. An Administrative Management Study by the Forest Service in 1962[3] resulted in the establishment of the INFORM (Information for Management) Group in 1963 under the leadership of the current Chief of the Forest Service, Max Peterson. Under the auspices of this group, investigations were made in information needs analysis and the data base management systems available at that time were evaluated in terms of Forest Service needs.[4]

In December 1971, funds and personnel were committed to the development of an information system for timber management using the GIM (Generalized Information Management) data base management system. Throughout 1972 all administrative levels were involved in determining the reporting requirements for each administrative level and the identification of the data needed to meet these requirements. Individual data files were then designed and the definitions of the data elements were established. Early in 1973, pilot testing was conducted using the Univac computer at the National Bureau of Standards in Washington, D.C. Due to the limited communication capacity of this computer, private facilities at El Segundo, California were obtained under General Services Administration contract. These additional communication facilities and the acquisition of remote terminals by the majority of National Forests permitted testing of the system nation-wide.

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[3]Hendee, Clare. 1962. Organization and Management in the Forest Service. Unpublished report. USDA Forest Service.

[4]Committee Work Plan. August 1964. Developing a Management Information System for the Forest Service.

SUMMARY 42F (TM-LUC-AREAST) TIMBERLAND USE SUMMARY DATE: 30 OCT 80
SUMMARY BY STATE (ACRES OF COMBINED HARDWOODS AND SOFTWOODS) PAGE: 1

STATE	PRODUCTIVE FOREST LAND: COMMERCIAL FOREST LAND: STANDARD	SPECIAL	MARGINAL	UNREG	TOTAL CFL	OTHER RESERVED	PRODUCTIVE DEFERRED	OTHER FOREST	WATER AND NON-FOREST	TOTAL NET NAT>L FOREST
ALABAMA	529,620	36,322	5,344	38,316	609,602	12,646	8,779	175	7,212	638,414
ALASKA	1,177,680	484,952	936,861	1,245,055	3,844,557	1,931,558	62,747	4,881,440	8,670,464	19,390,766
ARIZONA	1,992,918	147,228	343,089	73,480	2,556,715	82,600	35,730	1,808,550	6,731,050	11,214,645
ARKANSAS	1,647,789	0	510,986	162,758	2,321,533	26,024	52,207	27,328	36,970	2,464,062
CALIFORNIA	4,837,136	711,615	2,031,643	419,941	8,000,335	492,024	308,150	4,738,261	6,575,404	20,114,164
COLORADO	1,813,574	675,840	2,511,469	2,184,174	7,185,057	564,316	1,028,664	1,619,029	3,319,326	13,716,392
FLORIDA	669,355	18,471	7,485	45,662	830,937	19,916	42,642	160,498	36,812	1,090,841
GEORGIA	654,253	1,824	82,739	17,124	755,940	52,016	36,200	2,276	4,291	850,723
IDAHO	4,209,694	1,297,035	4,305,795	386,738	10,199,262	1,972,784	1,145,098	2,607,518	4,503,221	20,427,883
ILLINOIS	161,800	52,100	5,900	3,600	223,400	2,000	15,000	800	16,600	257,800
INDIANA	153,000	8,400	2,100	1,700	165,200	100	10,000	0	4,000	179,300
KENTUCKY	601,766	17,700	3,000	1,500	623,966	200	11,115	0	8,500	643,781
LOUISIANA	465,000	13,400	37,500	36,900	552,800	20,100	6,800	600	16,700	597,000
MAINE	29,700	6,300	1,400	300	37,700	0	0	8,100	200	46,000
MICHIGAN	1,996,560	334,840	30,928	41,326	2,403,654	23,200	43,243	71,600	172,500	2,714,197
MINNESOTA	1,441,700	97,200	193,000	23,300	1,755,200	731,300	400	125,900	204,100	2,816,900
MISSISSIPPI	1,020,671	17,468	11,275	23,961	1,073,375	1,069	8,707	4,587	49,877	1,137,615
MISSOURI	1,082,700	160,400	52,200	7,900	1,303,200	5,300	30,400	72,000	46,300	1,457,200
MONTANA	3,599,169	1,782,976	1,590,762	1,333,530	8,306,437	1,696,710	874,073	3,537,097	2,409,629	16,823,946
NEBRASKA	0	0	0	41,129	41,129	0	0	22,558	194,164	257,851
NEVADA	5,300	200	2,600	43,600	51,700	5,900	0	2,211,900	2,728,900	4,998,400
NEW HAMPSHIRE	319,700	97,800	14,100	10,100	441,700	20,400	42,500	165,100	13,300	683,000
NEW MEXICO	1,607,031	175,034	939,281	124,000	2,845,346	527,660	211,234	3,087,400	2,428,300	9,099,940
NORTH CAROLINA	663,068	9,804	292,762	25,151	990,785	49,086	87,469	9,785	13,448	1,150,572
OHIO	146,800	7,300	7,100	200	161,400	100	0	700	3,900	166,100
OKLAHOMA	164,029	0	21,676	43,278	228,983	0	12,410	2,952	1,664	246,009
OREGON	7,113,548	1,893,499	1,920,205	386,589	11,313,841	657,237	287,863	1,344,546	1,613,009	15,216,496
PENNSYLVANIA	378,100	71,100	23,200	5,000	477,400	4,300	9,600	800	16,400	508,500
SOUTH CAROLINA	480,516	7,998	46,648	21,278	556,440	6,061	18,087	10,823	11,949	603,360
SOUTH DAKOTA	908,919	35,296	45,195	47,155	936,565	1,190	7,729	36,269	142,385	1,124,138
TENNESSEE	358,024	58,300	124,324	18,600	559,248	3,700	24,952	13,400	6,598	607,898
TEXAS	543,835	16,957	914	31,098	592,804	1,130	11,210	0	56,615	661,759
UTAH	896,552	180,962	1,387,256	15,600	2,480,270	164,800	168,030	1,833,700	3,245,200	7,892,000
VERMONT	186,000	18,500	14,500	1,300	220,300	17,200	0	19,300	9,200	266,000
VIRGINIA	619,714	50,023	561,687	233,431	1,464,855	12,486	60,531	70,142	9,305	1,617,319
WASHINGTON	3,513,579	981,404	574,852	194,249	5,264,084	825,098	283,575	1,803,795	834,041	9,010,593
WEST VIRGINIA	503,240	173,414	115,673	12,997	805,324	35,400	57,839	22,873	17,583	939,019
WISCONSIN	1,013,636	190,400	30,800	12,326	1,247,162	19,016	33,573	124,326	70,957	1,494,944
WYOMING	849,873	494,671	1,027,471	651,030	3,023,045	928,567	303,342	1,271,411	3,124,999	8,651,364
TOTAL	48,265,554	10,316,633	19,903,720	7,965,376	86,451,287	10,913,194	5,339,898	31,717,449	47,355,073	181,776,901

FIGURE 2 - AN AREA SUMMARY EXTRACTED FROM THE LAND USE CLASSIFICATION DATA BASE

SUMMARY 42F (TM-LUC-AREAST) TIMBERLAND USE SUMMARY DATE: 30 OCT 80
REGION: 02 (ACRES OF COMBINED HARDWOODS AND SOFTWOODS) PAGE: 2
SUMMARY BY STATE - REGION 2

STATE	PRODUCTIVE FOREST LAND: COMMERCIAL FOREST LAND: STANDARD	SPECIAL	MARGINAL	UNREG	TOTAL CFL	OTHER RESERVED	PRODUCTIVE DEFERRED	OTHER FOREST	WATER AND NON-FOREST	TOTAL NET NAT>L FOREST
COLORADO	1,807,674	675,540	2,505,469	1,948,355	6,937,038	564,316	1,028,664	1,608,729	3,314,826	13,453,573
NEBRASKA	0	0	0	41,129	41,129	0	0	22,558	194,164	257,851
SOUTH DAKOTA	808,919	35,296	45,195	43,541	932,951	1,190	7,729	25,633	83,106	1,050,609
WYOMING	611,545	230,706	461,517	638,773	1,942,541	472,034	139,014	534,709	1,717,299	4,805,597
TOTAL	3,228,138	941,542	3,012,181	2,671,798	9,853,659	1,037,540	1,175,407	2,191,629	5,309,395	19,567,630

FIGURE 3 - A PARTIAL SUMMARY EXTRACTED FROM THE LAND USE CLASSIFICATION DATA BASE

This wide scale test permitted resolution of lingering design and operational problems.

At the Service-wide level, information was extracted from the data bases in 1975 to respond to specific information needs. A system of periodic, formal reports was instituted in 1976 and continues to date.

OPERATION AND MAINTENANCE OF THE SYSTEM

The Timber Management Information System is now maintained on the Department of Agriculture's Univac 1100/83 at Fort Collins, Colorado. Each Regional Headquarters and several National Forests have high speed batch terminals which can access TMIS. In addition, every National Forest has one or more demand terminals which can be used for this purpose.

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STATEMENT LIST TM-STAND WITH STAND-SIZE-CLASS EQ "10"
ANDD WITH FOR-SURVEY-TYPE EQ "4" ANDD WITH
SOFT-SAWTBR-MBF GT "10.0" LEG-LAND-DES STAND-ACRES
SOFT-SAWTBR-MBF#
```

TM-STAND ...		LEG-LAND-DES	STAND-ACRES	SOFT-SAWTBR-MBF
110601	10	36N008W05	70.0	12.844
110601	14	36N008W07	16.0	14.807
113009	5	35N005W08	17.0	14.748
113009	7	35N005W05	35.0	17.861
119411	2	34N001E22	29.0	13.339

Figure 4.--An example of a query and response from a STAND data base.

In practice, high speed batch terminals are used to load large quantities of data, such as new inventory data or quarterly timber sale program accomplishments. Editing and updating existing data is more efficiently accomplished by demand terminal.

The maintenance of the system is the responsibility of the Timber Management Staff Group. Although this group is a part of the Washington Office Division of Timber Management, it is located at the Fort Collins Computer Center in order to assist in solving user problems more efficiently.

Although TMIS currently employs the GIM Data Base Management System, it is not dependent upon this or any other data base management system. In fact, TMIS is currently being converted to the System 2000 data base management system, which offers capabilities and efficiency not available in the current system.

The principal objective of TMIS is to provide systematic means of furnishing consistent, reliable information about the timber resources of the National Forest System in a timely manner. Over the past five years it has met this objective in a noteworthy manner. Not only has it met current needs, but it has demonstrated its flexibility in responding to changing information needs. As the need for information about arid lands and their resources increases, the concept and framework of TMIS can be adapted to fulfill this need efficiently. The system has had the capability to satisfy changing information needs in the past and can be expected to do so in the future.

TMIS - UNA HERRAMIENTA PARA EL ALAMACENAMIENTO Y LA RECUPERACIÓN DE INFORMACIÓN DE RECURSOS

RESUMEN - El almacenamiento eficiente y la oportuna recuperación de información relativa a recursos naturales fo menta la eficiente administración de las tierras y de los recursos. Un sistema para almacenar y recuperar información relativa a la madera - TMIS - es descrito. Dicho sistema es util para almacenar información de inventario y registrar actividades administrativas, de actividades planeadas y de los logos obtenidos. Se describen los componentes del sistema al igual que la operación y el uso del mismo.

The Digital Thematic Mapping System as a Tool for Computerized Inventory of Resources[1]

Keith Guard[2]

The function of the digital thematic mapping system is to provide technical specialists with ready access to data in the form of specialized maps. Data from various sources may be used to form a resource inventory data base, a valuable tool for the further manipulation and analysis of data.

INTRODUCTION

The purpose of this paper is to describe how a digital thematic mapping system can be used as the basis for a computerized resource inventory data base. The system concept is based on the digital mapping system under development at New Mexico State University. I will first discuss the salient features of a digital thematic mapping system, using the NMSU system as a model. After that I will outline the functions of a data base system, then describe the method of structuring the mapping system to serve as a resource inventory data base.

Since most of you are not computer specialists, I will not discuss the details of implementation of the system on a computer. The description is functional; it defines what is done, not how it is done.

THE FUNCTION OF A MAPPING SYSTEM

The function of a digital thematic mapping system is to provide technical specialists with ready access to data in the form of special-purpose maps. The specialists may be highway engineers, agronomists, urban planners, geologists, or any other scientists or engineers who use data that are most effectively presented in map form. The maps produced are simple in form. They are working documents, produced for a specific purpose, in comparison with the multi-purpose general maps produced by conventional cartography.

The basic components of a digital mapping system, as with any digital data processing system, are data input, data editing, data storage, data manipulation and data output.

INPUTS TO A MAPPING SYSTEM

The inputs to our digital mapping system are varied. They include the following types.

1. Data digitized from conventional maps, such as the locations of roads, rivers, political boundaries, cities, etc.

2. Data digitized from aerial photographs or Landsat images. The usual procedure is for a specialist in a particular field to delineate specific interpretations on the photo. These interpretations, be they soil types, vegetation types, land use types, geological structures, or any other item of interest, are entered on the photo as polygons enclosing areas with specified characteristics.

3. Field data observations, entered from data tapes or manual records, keyed to the geographical location of the observation. Examples are species counts for flora and fauna, or precipitation measurements from meteorological stations.

4. Tabular data from textbooks or reports, entered via terminal or keypunch, keyed to the geographic location of the data.

5. Digital terrain tapes, giving altitude on a regularly spaced grid of points.

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[1]Paper presented at the Arid Land Resources Inventories Workshop. (La Paz, B.C.S., Mexico, November 30 through December 6, 1980)

[2]Dr. Keith Guard is Chief of the Applied Analysis Section of the Physical Science Laboratory, New Mexico State University, Las Cruces, N.M.

Data input may be any data that can be represented as a function of spatial location. Three types of data can be immediately distinguished: areal, linear, and point. The distribution of soil types, vegetation types, or any similar data is represented by an area that is bounded by a polygon on the map. Locations of roads, rivers, or utility lines are examples of linear features. Locations of wells and meteorological stations are examples of point features. On a small scale map, a city might be a point feature, while on a larger scale, it would be an area. On a medium scale map of a city, a street is a linear feature, while on a large scale map of a few blocks, the street is an area.

DATA STORAGE

Data storage must contain provision for three types of data: Identifiers of features, coordinates of features, and attributes of features. For each document digitized, a data file is set up containing identifiers of all features on that document. The identifiers serve as keys for the coordinate file and the attribute file.

The coordinate file contains X-Y coordinate pairs. Point features have only a single pair. Linear features are digitized as "strings" of coordinate pairs, and area features are defined by those strings which form a polygon enclosing the area.

Attributes of the features, whether areas defined by polygons, linear features, or points, are stored in a file with keys referring them to the features to which they apply. For any feature, one attribute serves as the defining characteristic. The defining characteristic on a soils map, for example, is a soil type, while on an altitude contour map it is the altitude range.

The attributes of an area feature include the area of the feature, its centroid, and the defining characteristic. For a linear feature, the attributes may refer to the entire feature or to only specified points. For example, stream flow at points along a river course may be stored as attributes of those points. "Tree" structures, such as river systems, and networks, such as streets, are stored as separate linear strings with the intersection points of other linear strings defined as attributes. For a point feature such as a meteorological station, the attributes may be the sequence of measurements as a function of time.

DATA EDITING

We at NMSU have an extensive repertoire of procedures used to check input data for errors and omissions and to edit the data files. These procedures will not be discussed here, since they do not apply to the topic under discussion.

DATA MANIPULATION IN A MAPPING SYSTEM

The data manipulations available in a mapping system include

1. Data selection, by data type and location;
2. Combination of data from two or more sources;
3. Scale conversion, to combine data from different sources on the same map, and to select the best scale for a given presentation;
4. Coordinate transformations, to refer data from different sources to a common reference system or to present data in a desired system;
5. Mathematical manipulations, such as finding the area for specified types of features or finding the distance between specified features;
6. Obtaining contours of equal value by interpolating from point data; and
7. Performing the logical operations "and", "or", and "not" on areal attributes and mapping the results. By using the logical operations, it is possible to describe areas with new defining characteristics, which are formed by any desired logical function of the existing characteristics.

The logical product operation serves as an excellent example of the type of data manipulations made possible by such a system. The relationship to be examined in this case is that between precipitation and erosion. Figure 1 is a map which shows the contours of average annual precipitation in Doña Ana County, New Mexico. Figure 2 shows predicted annual erosion rates for the same area. A typical question might be "What areas in Doña Ana County have more than 10 inches of precipitation per year and less than 0.2 acre feet per square mile of erosion per year?" Using a graphics terminal, the scientist working on the problem could have a visual display of this answer, shown in figure 3, within seconds.

OUTPUTS OF A MAPPING SYSTEM

The outputs of the digital thematic mapping system are usually in map form, but tabulations of data, as referred to specific areas or points, may also be obtained. Examples are tabulations

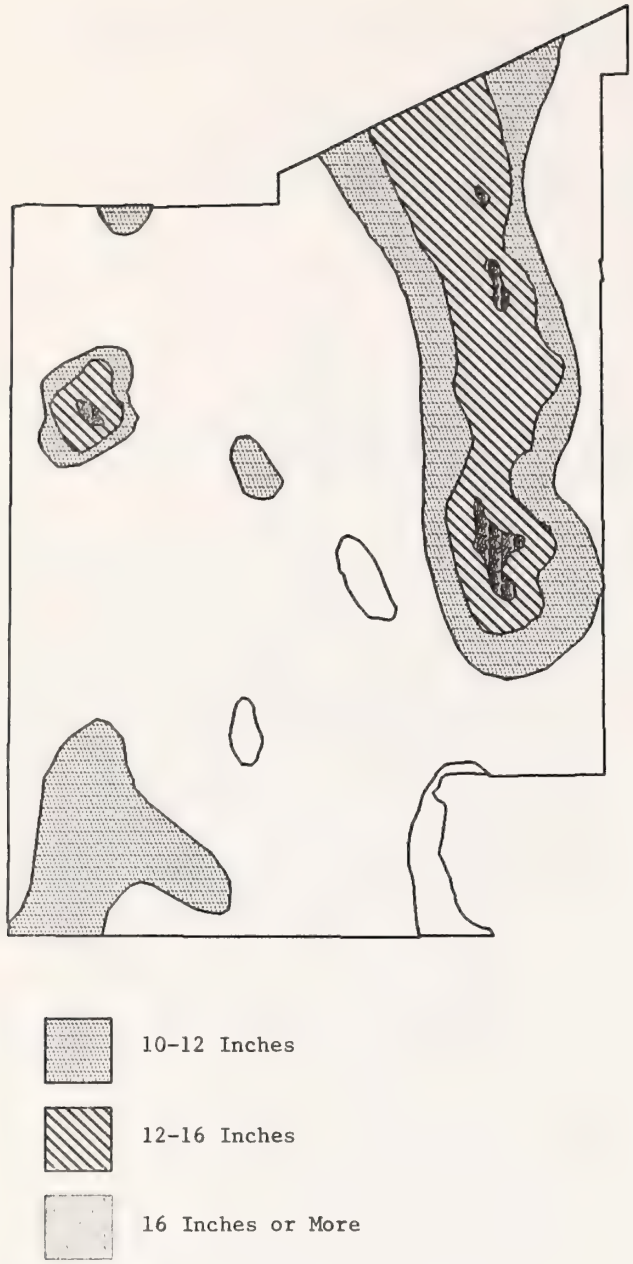

Figure 1 Average Annual Precipitation
for Doña Ana County, New Mexico

of acreages for different crop types on a specified map, or tabulations of rainfall for specified sites. The map outputs are usually obtained directly on computer ouput media. A plotter with capability to provide toning for specified areas and automatic labeling, provides plots such as are shown in the illustrations for this report. The size limit on such plots is 11" in width, by any desired length.

A flat-bed plotter may be used to obtain larger plots, or to plot data derived from the digital system on printed maps.

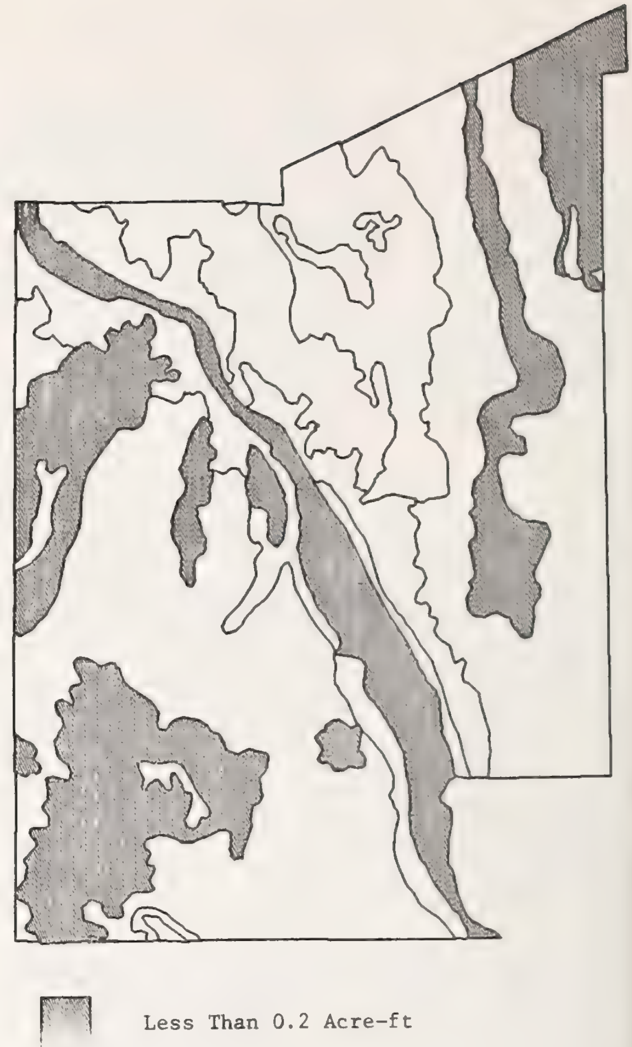

Figure 2 Predicted Annual Erosion Rates
for Doña Ana County, New Mexico

For preliminary examination of results before plotting, a graphics terminal is desirable. The application specialist who uses the system can use the graphics terminal to search for data combinations to solve his problem. He can try out possible techniques to determine their results, without waiting for hard copy plots.

FUNCTION OF A DATA BASE SYSTEM

A data base system is basically a system to manage a large number of data files for multiple users. The term "data base" refers to a collection of files which contain all of the data available on a specified subject. A resource inventory data base for a specified area would contain files with data on geography, geology, soils, crops, weather, roads, public utilities, ground water, etc.

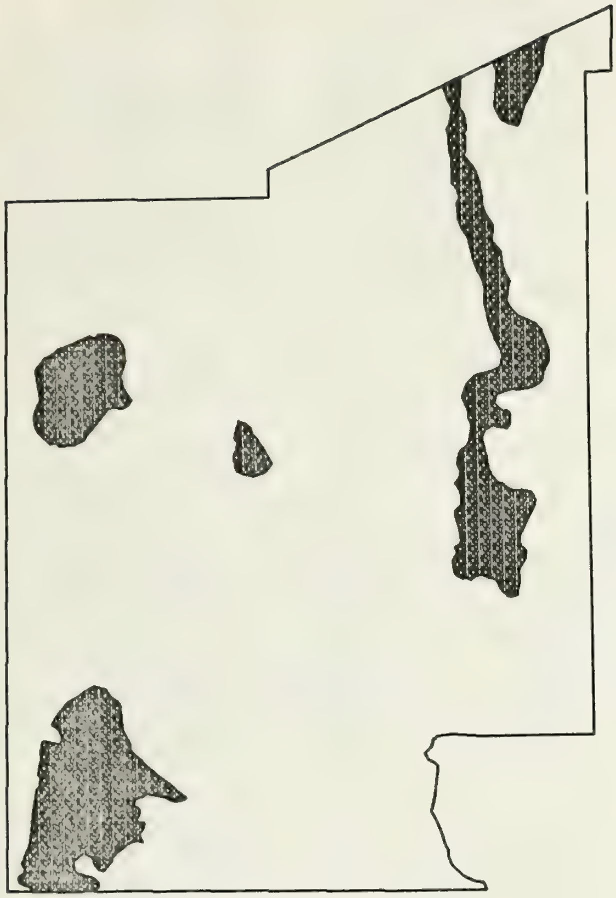

Figure 3 Logical Combination Depicting Those Areas of Doña Ana County, New Mexico, Which Have More Than 10" of Precipitation per Year and Less Than 0.2 Acre-ft of Erosion per Square Mile per Year

The function of a data base system is to enable use of the data in terms that are meaningful to the user. It frees him from the restriction of defining his data in terms of the management of the physical files of the computer system. In many computer applications, the user of the program is also the person who manages the files. In situations in which there are multiple users, using multiple programs, each of which may access multiple files, a more formal system is necessary.

A properly designed data base system provides the user with descriptions of the logical structure of the data. The physical structure of the data may be quite different from the logical structure. The physical structure is designed by computer specialists to optimize the use of the computer resources available. The logical structure is designed to provide for

1. Ease of use by individuals who are specialists in a scientific or engineering discipline, not computer scientists;

2. Flexibility of application, so that new types of data may be added or quantities of data may be changed without changing the logical description or the applications programs;

3. Versatility, in that numerous applications programs can use different combinations of data from the data base;

4. Control over data, so that any additions, deletions or changes to data are made by authorized individuals and documented for the users.

A DIGITAL MAPPING SYSTEM AS A DATA BASE SYSTEM

In any data base, the data must be filed under a logical structure. In a resource inventory data base, all data items have one common characteristic: each is referenced to a geographic location. For this reason, a digital mapping system provides the logical structure for such a data base. In our system, that structure is the USGS system of "Quad" maps: the 1:250000 series, or 1 x 2 degree maps; the 1:62500 or 15 minute maps and the 1:24000 or 7 1/2 minute maps.

These maps are referred to as primary references or as primary sources. Other data sources, which may be local maps, or may be aerial photos or satellite images, are secondary sources, which are referenced to the primary references as described below.

In the NMSU system, all data digitized from a particular source, together with the auxiliary data on the features digitized, are stored in a file referenced to the source. The aggregate of data from each source is referred to as the data set from that source.

1. The position data in each data set is stored in reader coordinates. Reader coordinates are the X-Y coordinates obtained directly from the digitizing tablet.

2. Each data set has appended to it a record identifying the source document and the date on which it was read.

3. Each data set contains a set of reference points, identified with a reference map.

4. The basic references are latitude and longitude. For all maps containing latitude and longitude lines, a set of map coordinates with known latitude and longitude lines are measured and stored

as reference points. From these measurements combined with the known latitude and longitude we compute and store the coefficients of a transformation between reader coordinates and latitude and longitude, for that map.

5. For local maps, which do not contain latitude and longitude references, and for aerial photos and satellite remote sensing imagery, a set of reference points, identifiable both on the local map or photo image, and on a reference map, are identified and digitized. Then by a process of successive transformations the data from the secondary source may be referred to the latitude-longitude system.

6. A master reference file is kept, giving the latitude and longitude coordinates of the reference points of each source record, whether it is primary or secondary.

7. When it is desired to search the data base for data on a particular site, the site coordinates are entered. The site coordinates may be entered in terms of

   a. Latitude and Longitude,

   b. UTM coordinates with a specified reference meridian,

   c. Lambert projection coordinates, or

   d. Map coordinates on a specified primary or secondary source.

   If the site coordinates are not in latitude and longitude, they are converted to latitude and longitude by standard routines and a search is made of the reference file to find the identifiers of all maps containing the specified site.

8. The search request may contain qualifiers, asking for certain types of data only, or may ask for all data on a certain site.

9. As a result of the search request, a list of available data on the selected site will be presented to the user.

10. The user may request copies of the source maps, or he may request derivative maps to be obtained by internal manipulation.

THE NMSU SYSTEM

Our system is implemented on an Amdahl V5 computer, using the APL language. APL is a high level programming language with the capability of performing vector and matrix operations by use of a single APL operator symbol. This feature, combined with the fact that APL is a remote-terminal-oriented, interactive system, allows a user to develop new applications in a fraction of the manhours and with only a fraction of the computer resources required by other languages.

To be truly effective, a digital thematic mapping system should be on-line, available to the users through interactive terminals. Such a system provides a high degree of responsiveness to the user's requests and also allows the user to tailor his output to his needs of the moment.

Our system presently uses a GTCO Datatizer digital table to digitize map data for inputs. We have a ISC Model 8000 color graphics terminal for data checking, editing, and preliminary examination of output data before plotting. For hard copy output we use a Versatec plotter on the Amdahl system for smaller plots and a Data Tech 3454 flat-bed plotter for larger plots and for the overplotting of existing maps.

RESUMEN

Este ensayo describe como un sistema digital de cartografía temática puede ser usado como una base de datos computadorizado para realizar inventarios de recursos naturales. Se usa como modelo un sistema actualmente en desarrollo por la Universidad Estatal de Nuevo Mexico.

En las siguientes lineas se describe un modo de estructurar el sistema. La descricción enfatiza los propósitos del sistema más que los detalles referentes a su implementación en una computadora.

La primera función de un sistema degitalizado de cartografía temática es proporcionar a los cientificos mapas sencillos para propósitos específicos que puedan ser usados como instrumentos para análisis de diferentes problemas.

Las partes básicas de tal sistema son la entrada de datos, la corrección de errores en estos, el almacenamiento de datos, la realización de operaciónes aritméticas y lógicas, y la salida de resultados. Los datos pueden ser obtenidos usando mapas convencionales, fotografías aéreas, imágenes del satélite Landsat datosde campo, datos tabulados en informes impresos, o cintas digitalizadas de terreno.

Todos datos de entrada deben ser representados como función de su ubicación geográfica. Tres clases de rasgos geográficos son facilmente diferenciados: Áreas, líneas, y puntos.

El almacenamiento de datos debe dar cabida a tres tipos de datos sobre cada rasgo de interés: Los signos de identificación, coordenadas de estos, y las caracteristicas de ellos. Un archivo de datos debe ser establecido para cada documento digitalizado, incluyendo los signos de identificación de todos los rasgos del documento. Estos signos servirán como llaves de los archivos de las caracteristicas y de las coordenadas. El archivo de coordenadas contiene pares de coordenadas X-Y. A los rasgos de punto corresponden un solo par de coordenadas X-Y. Los rasgos lineales son digitalizados como 'tiras' de pares de puntos X-Y. Rasgos de áreas son descritos por las tiras las cuales conforman un polígono el cual contiene al área.

El archivo de caracteristicas contiene por lo menos un item de datos por cada rasgo, el cual es la caracteristica identificadora del mismo, y puede contener cualquier número de otras caracteristicas conforme a los circunstancias.

Las operaciones aritméticas y lógicas usadas en un sistema de cartografía incluyen: seleccionar datos de acuerdo con el tipo y ubicación geográfica, combinación de datos desde dos o mas fuentes, cambio de escala, conversión de coordenadas desde un sistema al otro, realizar operaciones lógicas en las caracteristicas identificadoras de los rasgos de área, y computar contornos de valores iguales mediante la interpolación de los datos de punto.

Los datos de salida de un sistema digitalizado de cartografía temática son por lo común en forma de mapas, pero tabulaciones de datos tambien pueden ser obtenidas. Los mapas comunmente son presentados en los ploteadores de salida continua de la computadora, que proporcionan plotes con rótulos y con áreas identificadas por varios tipos de patrones, como se muestra en las illustraciones incluidas en este ensayo. Para obtener mapas más grandes, o para plotear datos del sistema digital sobre mapas ya impresos, un ploteador de mesa llana puede ser usado.

Una terminal remota gráfica es útil para la inspección prelimar de los resultados antes de plotearlos. El científico que usa el sistema puede utilizar la terminal gráfica para buscar combinaciones de datos para solucionar su problema determinado y para probar varios métodos de análisis sin esperar a que los plotes sean impresos.

Un sistema de bases de datos tiene fundamentalmente el propósito de manejar un gran número de archivos de datos para multiplos usuarios. Su función es proporcionar los medios del almacenamiento y recuperaracion de datos. La base de datos es un conjunto de archivos los cuáles contienen todo los datos disponibles pertienentes a un tópico específico.

La estructura lógica de la base de datos debe ser diseñada para ser fácilmente usada por cientificos y ingenieros no expertos en programación de computadoras. El sistema debe ser sumamente versátil, para poder ser usado por diversos programas de aplicaciones los cuales usen varias combinaciones de datos.

Al mismo tiempo, el sistema debe proporcionar control sobre los datos, de modo que cualquier cambio es efectuado por personas autorizadas quedando esto debidamente documentado para el conocimiento de los distintos usuarios. La estructura física del sistema debe ser diseñ ada por peritos en la ciencia de las computadoras para optimizar el uso de los recursos disponibles, librando al usuario del requisito de una comprención detallada del funcionamiento de la computadora, y de la responsibilidad de mantener la base de datos.

Todos los itemes de datos en una base para el inventario de recursos naturales tienen una caracteristica común: Cada uno tiene una ubicacion geográfica que puede ser usada como llave de referencia. A causa de esto, un sistema digitalizado de cartografía proporciona la estructura lógica para tal base de datos.

Chihuahuan Desert Flora Data Bank[1]

Alicia Roman Alemany and Domitila Cuadra Vasquez[2]

Abstract.--The written information on the Mexican Chihuahuan Desert flora, for its quantity as well as its diversity, justifies the creation of a Data Bank which, as well as helping with the study of the flora in situ, could be used as support for the carrying out of development programs in this marginated region. The organization of the Data Bank, working methodology, species, families, uses for and chemicals contained within the flora are presented.

INTRODUCTION

In the Applied Chemistry Research Center (CIQA) we have begun the localization, analysis and classification of the information which exists on the vegetal species of the Mexican part of the region denominated the Chihuahuan Desert.

Politically, the Chihuahuan Desert occupies parts of the states of Chihuahua, Durango, Zacatecas, San Luis Potosi, Coahuila and Nuevo Leon and the inclusion of a small part of the state of Tamaulipas is under discussion. It extends approximately from latitudes north 34°20' to 22°15' between the East and West Sierras Madre, occupying an area of 350,831.73 Km^2.

The irregular geography, with large mountain chains, the differences in height, the erratic rainfall, the fluctuating temperature and sunlight, among other factors, determine the existence of a numerous and varied flora.

This interesting territory has merited the attention of numerous investigators, Mexican and from other countries, and their work appears in many publications. For the purpose of delimiting the study region for the present task, the limits set by Marshall Johnston (1975) based on vegetation type have been used.

[1]Paper presented at the Symposium on Inventories of Arid Zone Natural Resources, La Paz, Baja California Sur, Mexico, December 1-5, 1980.

[2]Researchers at the Centro de Investigación en Química Aplicada (Applied Chemistry Research Center), Saltillo, Coahuila, Mexico.

ORGANIZATION OF THE DATA BANK

Seeking a method that would allow us, in the first stage, to localize the maximum amount of information, it was decided to revise all the heterogeneic documented material which could be found in libraries and other national institutions. It was also decided to revise complete collections of specialized national and foreign journals.

The information that has been compiled to date has been organized as shown in figure 1.

To date we have detected the presence of some 2,300 vegetal species in the Chihuahuan Desert, which, in our opinion, correspond to 686 genera from 127 families. A preliminary index card has been made out for each species as shown in figure 2. Another type of index card contains all the genera and species until now detected in each family (fig. 3).

The chemical information has been documented based on the chemical family and each one of these, in turn, has been broken down to the component substances and their quantities, when these figures are known (fig. 4).

A use classification for each species has been established, based on large use groups, and the plant organ or organs used in each group are specified (fig. 5).

Finally, there is the library index card as shown in figure 6.

Within these five types, to date 3,570 index cards have been elaborated. CIQA hopes to computerize this material in the near future.

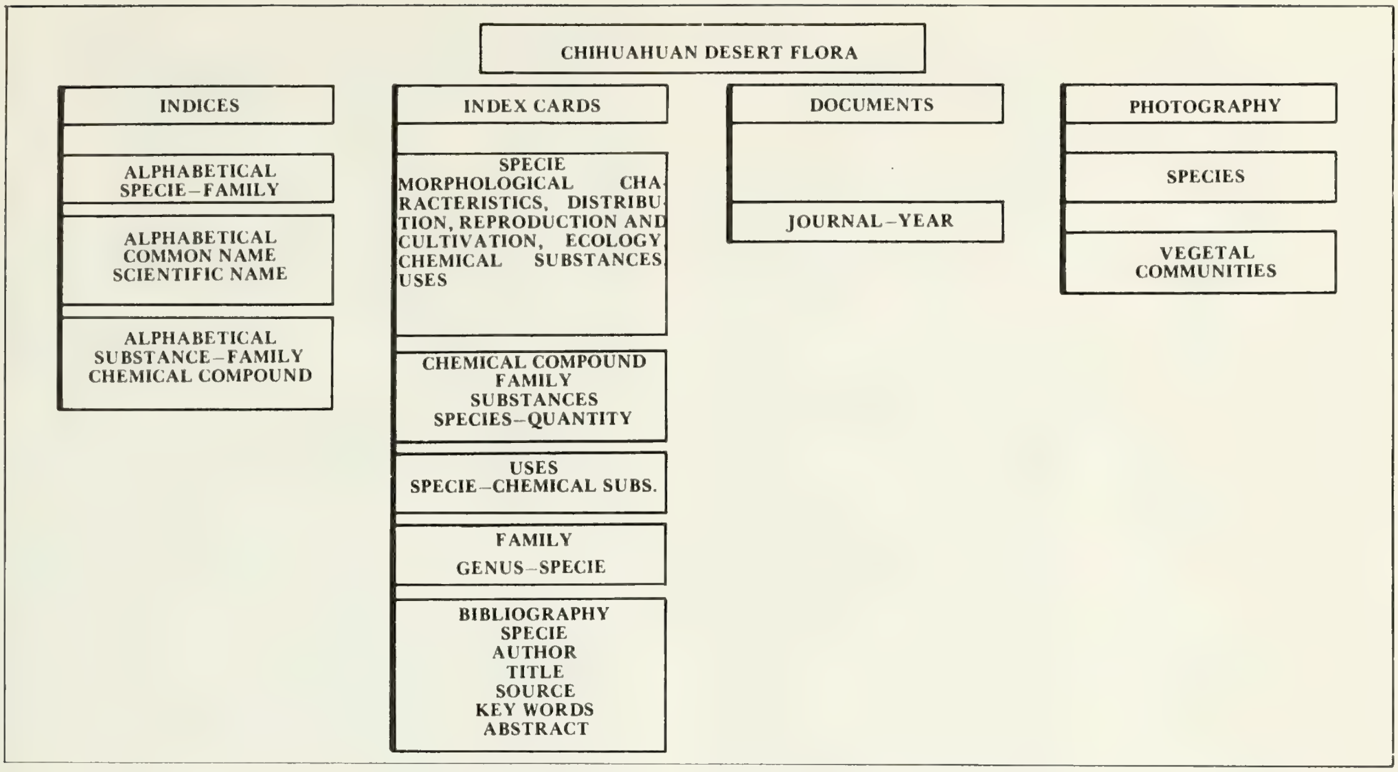

Figure 1.

CIQA

CHIHUAHUAN DESERT FLORA

SPECIE: *Carnegiea gigantea* (Engelmann) Britton and Rose.

SYNONYMS: *Cereus giganteus* Engelm.
Pilocereus engelmanii Lem.

COMMON NAME(S): Sahuaro, saguaro, pitahaya.

DISTRIBUTION: Desert zone between the Gila and Colorado rivers and extending from Arizona to the north of Sonora and Chihuahua.

DESCRIPTION: 15 or more meters in height. Simple or branched stems like candelabras, the branches are more than 30–65 cm ϕ, dark green. Ribs 12–24, obtuse, 1–3 cm in height; areolas between 2–2.5 cm apart with brown felt, almost joining the superior parts of the branches. Curved thorns, the center more robust, 7 cm long, gray with dark points. Flower areolas –superior– with needle–like thorns, yellowish brown. Flowers 10–12 cm long and 9–12 cm ϕ when corola extended: thick outer segments of perianth, greenish white, white interiors; wide and short tube scales. White and numerous stamens. Thick style 5–6 cm long, 12–18 stigma lobes. Scaly ovary with woolly axilas and numerous ovules. Red or purple fruit 6–9 cm long, with small triangular scales and slightly sugary flesh, when mature they dry and fall.

ECOLOGY: Grows on rocky mountain sides, at height and in the canyons.

COMMON USES: Stems for building shacks and as fuel. On compressing the fruit a sugary product is extracted, similar to the Opuntia fruit syrup. The fruits are harvested before they dry and are widely utilized. The seeds contain oil and are used to prepare a type of "pinole".

CULTIVATION:

VARIETIES:

CHEMICAL SUBSTANCES:
- Contains 0.7% alkaloids in the stem. Bruhn, J.G., Econ. Bot. 25(3): 320–329, 1971.
- Contains carnegine alkaloid. Heyl, G., C.A. 23:1211, 1929.
- Contains dopamine, gigantine and salsolidine alkaloids. Bruhn, J.G., Econ. Bot. 25(3):320–329, 1971.
- Contains steroidal sapogenin 31–norcycloartenol in the unsaponifiable fraction of the pollen. Cruse, R.R., Econ. Bot. 27(2): 210–230, 1973.
- The syrup prepared from the fruit contains 50 mg of proteins (N x 6.25) per g dry solid. Calloway, D.H. et al., Ecology of Food Nutrition 3:203–211, 1974.
- Contains various types of gum. Krochmal, A. et al., Econ. Bot. 8(1): 3–20, 1953.

Figure 2.

C I Q A

CHIHUAHUAN DESERT FLORA

FAMILY:	CRUCIFERAE (o Brassicaceae)
Asta	*schaffneri*
Brassica	*campestris*
Descurainia	*pinnata*
Eruca	*sativa*
Lepidium	*lasiocarpum*
Lesquerella	*argyraea* *diffusa* *fendleri* *lasiocarpa var. lasiocarpa* *mexicana* *mirandiana* *purpurea*
Nerisyrenia	*camporum* *castilloni* *gracilis* *(greggia) camporum* *incana*
Poliomintha	*marifolia*
Sisymbrium	*hispidulum* *linearifolium*
Synthlipsis	*greggii* *greggiihispidula*

Figure 3.

C I Q A

CHIHUAHUAN DESERT FLORA

CHEMICAL COMPOUND FAMILY:	STEROIDAL SAPOGENINS
SUBSTANCE:	SMILAGENIN
Agave funkiana	0.8 g x Kg (dry)
Agave lecheguilla Torr.	5.0 g x Kg (dry)
Yucca australis Engelm.	0.2 g x Kg (dry)
Yucca carnerosana Trel.	0.5 g x Kg (dry)
Yucca elephantipes Regel	0.6 g x Kg (dry)
Yucca filifera Chabaud.	0.5 g x Kg (dry)
Yucca jaliscensis Trel.	1.0 g x Kg (dry)
Yucca reverchoni Trel.	0.6 g x Kg (dry)
Yucca rostrata Engelm.	1.6 g x Kg (dry)
Yucca carnerosana Trel.	0.5 g x Kg (dry)

Marker, R.E. et al., J. Am. Chem. Soc. 65: 1199–1209, 1943.

Yucca carnerosana Trel.	Produced in young plant in March, 3 months before the flowering period: 38%
Yucca schottii Engelm.	Produced in March, 3 months before flowering: 15% of total. In flowers: 20% of total.

Marker, R.E. et al., J. Am. Chem. Soc. 69:2167–1230, 1947.

Figure 4.

C I Q A

CHIHUAHUAN DESERT FLORA

USE:	PRODUCTION OF REFRESHING DRINKS
Ephedra spp.	With the dry flowers and the stems a tasty tonic drink is made.
Thelesperma longipes	In New Mexico it is used as a substitute for tea, called "cota".

Krochmal, A. et al., Econ. Bot. 8(1): 3–20, 1953.

Opuntia spp.	With the watery extract of the carbonated fruit flesh a soft, pleasant–flavored drink is made.

Cruse, R.R., Econ. Bot. 13(3):243–254, 1959.

Fouquieria splendens	The Coahuila indians of southern California make an infusion with the flowers.
Prosopis juliflora	From the ground fruit a flour and a pleasant, nutritive drink are obtained. The toasted and ground seeds are mixed with coffee. The cooked leaves are known as "mesquite balsam".

Quintanar, F., printed IMRNR, 1961.

Agave atrovirens	The sugar water obtained from the floral peduncle is consumed fresh or fermented as "pulque".

Rzedowski, J., Ed. IMRNR, 1964.

Figure 5.

Agave lecheguilla
C I Q A

LIBRARY CARD
NATURAL RESOURCES PROGRAM

KEY:

AUTHORS: Wall, M. E. and C. S. Fenske.

TITLE: Steroidal Sapogenins. LXI. Steroidal Sapogenin Content of Seeds.

JOURNAL:

KEY WORDS: Saponins, sapogenins, glucoside, steroidal saponin, steroidal sapogenin, hecogenin, manogenin, smilagenin, gitogenin, sarsasapogenin, tigogenin, *Agave*, *Yucca*, *Nolina*.

SOURCE: Econ. Bot. Vol. 15 No. 2: 131–132, 1961.

ABSTRACT: Presents results of analysis of steroidal sapogenin content in the seeds of various species of *Yucca*, of two *Agave* and one *Nolina* and indicates the sapogenins found in leaves. Concludes that in the *Yucca* species there is a higher content of sapogenins in the seeds.

Figure 6.

Using some aspects of the compiled information, we present below a classification of some Chihuahuan Desert species, under four main headings, showing their current utilization as well as future potential.

1. Fuels

Traditionally the inhabitants of the region have used components of the flora as energy resources, either using the whole plant or its residues in those places where some kind of primitive industrial exploitation is carried out.

1.1. Plants

Prosopis juliflora is used as firewood and charcoal. Some of the 49 species of the *Quercus* genus which exist in the Chihuahuan Desert are used as firewood.

1.2. Residues

The residues or bagasse which remain after the extraction of wax from candelilla, rubber from guayule or "ixtle" fiber from lechuguilla or *Yucca* constitute fuels which are not fully exploited, mainly due to transportation problems.

2. Chemical Products

2.1. Products with Biological Activity

2.1.1. Plaguicides (table 1).

2.1.2. Pharmacology Products

For centuries plants have been used in the treatment of certain diseases. Although chemicals with physiological actions have now been synthesized, plants continue to be used (table 2).

Table 1.--Chihuahuan Desert species with plaguicidal action

Species	Observation	Action
Ricinus communis	Substances contained in the leaves & young stems	Insecticide
Artemisa spp.	Aromatic oil	Repellent for insects
Croton texensis		Insecticide
Larrea tridentata	Substances contained in the resin	Fungicide
Datura stramonium	Alkaloid contained in the plant	Nematodicide
Nicotiana glauca	Alkaloid contained in the plant	Afidicide

Table 2.--Medicinal uses for the Chihuahuan Desert plants

Use	No. of Species
Digestive complaints	24
Respiratory problems	14
Kidney diseases	6
Skin diseases	5
Venereal diseases	3
Rheumatism	6
Arthritis	4
Asthma	4
Allergies	1
Measles and similar	4
Diabetes	2
Vertigo	4
Amenorrhoea	1
Psychic diseases	2
Laxatives and purgatives	6
Anti-haemorrhage	5
Contraceptives	2
Anti-haemorrhoid	1
Tiredness	4
Analgesic	12
Febrifuge	5
Emetic	2
Emenagog	2
Disinfectant	2
Healing (wounds)	11
Narcotic	2
Dandruff treatment	1

2.1.2.1. Antibiotics

This action has been observed in various species in the zone. In the cases of *Lophophora williamsi* and *Pelecyphora aselliformis* it is probably due to the presence of hordenine; a specie of the *Brassica* genus possesses substances which inhibit *Aspergillus niger* and *Trichophyton rubrum*; the juice from the leaves of *Ricinus communis* presents a micobactericidal effect; *Reseda lutea* and *Cardiospermum halicacabum* act on *Staphylococus aureus* and *Cardiospermum* has the same effect on *Bacteria coli*. All of the following have various actions: *Aloe vera*, *Ambrosia artemisiifolia*, *Lantana camara*, *Rumex crispus*, *Solanum nigrum*, *Parthenium hysterophorus*, *Salix exiqua*, *Yucca baccata*, *Nicotiana trigonophylla*, *Triticum aestivum*, *Atriplex semibaccata*, *Baccharis glutinosa*, *Carya illinoensis*, *Nothoscordum bivalve*, *Parthenocissus quinquefolia*, *Cynodon dactylon*, *Quamoclit coccinea*. Table 3 shows the total number of species which act on the microorganisms indicated.

2.1.2.2. Steroidal Sapogenins

Two genera, *Yucca* of the LILIACEAE family and *Agave* of the AMARYLLIDACEAE family, constitute the principal sources of these substances (table 4).

Table 3.--Antibiotic activities of Chihuahuan Desert species

Activity on	No. of Species
Bacterias Gram^{+}	35
Bacterias Gram^{-}	14
Mycobacteria	20
Fungi	5
Yeasts	7
Virus (Vaccinia virus)	1
Protozoa (Entamoeba histolytica)	2

2.1.2.3. Sterols

The presence of sitosterol has been found in 10 species, the majority from the AMARYLLIDACEAE and LILIACEAE families.

2.1.2.4. Alkaloids

These substances are abundantly represented in some plant families, especially in the CACTACEAE (table 5).

2.1.2.5. Hypoglycemiants

In relation to the treatment of diabetes, the presence of some substances has been reported in the species of the region.

The extract from species of the Opuntia genus contains an anti-diabetic factor which has an advantage over insulin - it can be taken orally. It is also better than Orinase as it has no side effects. Garcia (1955) called this factor "plantisul" or plant insulin.

Also Agave lecheguilla contains xilitol, which is sweeter than sucrose and is not digestible and has therefore been approved for use in diabetes cases.

Quamoclit coccinea and Ricinus communis present hypoglycemiant action.

2.1.2.6. Laxatives

The mucilage of Carnegia gigantea and some species of the Opuntia genus have a laxative action. The oil from the Ricinus communis seed has a purgative action. The presence of aloine in the sap of the Aloe vera leaves gives them laxative and purgative properties.

2.1.3. Enzymes

Apart from peroxidase, various species contain other enzymes. In Opuntia ficus-indica the presence of the isomerase of glucose 6 phosphate has been determined. Some species of the Opuntia genus contain dioses. Castañeda et al (1943) have described some characteristics of the activity of the proteolytic enzyme from the latex of Euphorbia antisyphilitica in the presence of oxidants and reducers. They have proposed the name of "euforbaina C" for the enzymatic complex of this species. An enzyme similar to papain has been obtained from Solanum eleagnifolium and the activity of the lipase contained in Ricinus communis seeds has been studied.

2.1.4. Anti-cancer Agents

This action has been reported in Prosopis juliflora, Quamoclit coccinea and Ricinus communis.

2.1.5. Coagulants

Substances capable of coagulating milk have been found in the fruit of Solanum eleagnifolium and the bark of Prosopis juliflora.

2.1.6. Oxytocics

The root of Cucurbita foetidissima presents oxytocic activity.

2.1.7. Plant Growth Inhibitors

Extracts which inhibit the growth of some plants have been obtained from Prosopis juliflora. The tests were carried out on tomatoes. The substances which cause this effect were isolated and are byankangelicin, isopimpinellin and a derivative of isobergaptein, the latter being the most active.

Table 4.--Steroidal sapogenins in Chihuahuan Desert species

Steroidal Sapogenin	No. of species which contain it
Clorogenin	3
9-Dehydrohecogenin	4
9-Dehydromanogenin	1
Diosgenin	3
Gentrogenin	6
Gitogenin	10
Hecogenin	14
Kammogenin	2
Manogenin	13
Mexogenin	3
Neogitogenin	2
Neohecogenin	1
Neomanogenin	2
Neotigogenin	2
Samogenin	3
Saponin	3
Sarsasapogenin	11
Smilagenin	11
Solasodine	1
Texogenin	1
Tigogenin	9
Willagenin	1
Yuccagenin	2

Table 5.--Alkaloids in Chihuahuan Desert species

Alkaloid	Number of species which contain it
Anhalamine	1
Anhalidine	2
Anhaline	4
Anhalinine	1
Anhalonidine	1
Anhalonine	2
Atropine	1
β-phenethylamine	2
Carnegin	1
Anhalonine chloride	1
Lophophorine chloride	1
Peyotine chloride	1
Criogenin	1
Dopamine	1
Ephedrine	1
Gigantine	1
Hyoscyamine	1
Hioscine	1
Hordernine	4
Kokusaginine	1
Lantadene A	1
Lophophorine	1
Mescaline	1
N-N-Dimethyl-3-hydroxi-4,5 Dimethyoxyphenethylamine	1
N-Methyl-β-Phenyletylamine	5
N-Methyl-3,4-Dimethoxyphenethylamine	2
N-Methyl Mescaline	1
N-Methyl Thyramine	2
O-Methyl-d-Anhalonidine	1
Peyotine	2
Lophophorine picrate	1
Pilocereine	1
Retusine	1
Ricinine	1
Salsolidine	1
Solanine	1
Mescaline sulphate	1
Thyramine	3
Undetermined	61

2.1.8. Plant Transpiration Reducers

This activity is presented by the extracts obtained from the veins of Prosopis juliflora and the leaves of Schinus molle and Opuntia ficus-indica. Their action lowers the transpiration by 15%, 10% and 10% respectively.

These natural reducers have an advantage over the synthetic ones in that they are not toxic for the plants and do not affect their yield.

2.2. Soaps and Detergents

Traditionally, plants have been used in the Chihuahuan Desert as substitutes for soap.

Of the better known species, for their popular use in the region, the following are emphasized: various species of the Solanum genus which contain various quantities of solanine; species of Agave, like A. schotti and A. lecheguilla which contain saponins in the leaves and roots; Cucurbita foetidissima which contains saponins in the fruits and Condalia lycioides which contains them in the roots. Some species of the Yucca genus present similar properties.

The oil of Ricinus communis is used in the manufacture of soaps and shampoos.

2.3. Cosmetics and Perfumes

The mucilage from Opuntia species is used in the cosmetics industry, probably due to its therapeutic properties for the skin; Euphorbia antisyphilitica wax is used in the making of lipstick and ointments.

The essential oils contained in the species of the Opuntia and Acacia genera, especially in A. farnesiana, are used in perfumes. The oil from the seed of Ricinus communis has applications in perfumes, ointments, skin creams and hair cosmetics.

2.4. Organic Coatings

2.4.1. Adhesives

The gums obtained from Opuntia species, principally from O. ficus-indica, and from Agave atrovirens and Prosopis juliflora present possibilities for use as adhesives; also the resins from Larrea tridentata and Parthenium argentatum.

2.4.2. Paint, Varnishes and Laquers

The modified oil from the seeds of Ricinus communis is used in the paint, varnish and laquer industries. Yucca filifera and Oenothera rosea can also be used for paints and varnishes due to the linoleic acid contained in their seeds. The resins obtained from Larrea tridentata, Parthenium argentatum, Lantana camara, Solanum nigrum, Schinus molle and Fouquieria splendens find application in the production of varnishes.

2.5. Additives for Plastics

In this respect, the oil from Yucca filifera seed could be used; currently that from Ricinus communis is employed.

2.6. Additives for Elastomers

These include the antioxidant obtained from Larrea tridentata, the peptizant from Parthenium argentatum resin and wax from Euphorbia antisyphilitica.

2.7. Colorants

The various and ostentatious colors of the flowers and fruits of Opuntia and other species are

due to the presence of betaxantines, indicaxantines, xantofil, antocianines, carotene and flavonoids. Their value lies in the fact that they can be used as food colorants as well as for the dying of hide, textiles and baskets.

Fourteen species have been reported in this group.

2.8. Lubricants

Ricinus communis is the only specie reported as raw material for the manufacture of lubricating substances.

2.9. Curing Agents

Tannins have been detected in 32 species in the region, with emphasis on Acacia farnesiana and Rumex hymenosepalus for their high content.

3. Materials

This group comprises the raw materials necessary for construction and the manufacture of articles like furniture, ropes and cleaning utensils.

3.1. Pulp and Cellulose

Various Chihuahuan Desert species show utilization possibilities for the manufacture of paper and cardboard. In some cases they can be used integrally and in others it is possible to use the cellulosic residues which remain after exploitation for other purposes.

To date an industrializable cellulosic content has been found in Yucca elata, Nolina texana, Dasylirion spp., Agave lecheguilla, Opuntia ficus-indica and other Opuntia, Prosopis juliflora, Ricinus communis and Indigofera suffruticosa.

3.2. Textiles and Fibers

Traditionally, Agave and Yucca have been used for the extraction of fibers in the Chihuahuan Desert. A. lecheguilla and Y. carnerosana have been preferred for their hard fiber.

3.2.1. Bags

Yucca filifera, Y. carnerosana and Agave lecheguilla.

3.2.2. Material (cloth)

Yucca carnerosana, Agave atrovirens and A. lecheguilla.

3.2.3. Ropes

Yucca elata, Y. filifera, Y. carnerosana, Agave atrovirens, A. lecheguilla, A. striata, A. asperrima and Abutilon incanum.

3.2.4. Handcrafts

Material, belts, mats, hats and domestic articles are made of fibers, leaves and bark from species such as Yucca elata, Nolina texana, Prosopis juliflora and Dasylirion spp.

3.2.5. Footwear

The leaf fibers of Yucca elata and Yucca carnerosana are used in the manufacture of insoles and sandals.

3.2.6. Cushions and Fillings

The fibers of Yucca carnerosana, Tillandsia recurvata and T. usneoides are used in the manufacture of cushions and fillings; the waste fibers of Agave lecheguilla as burlap in upholstery and the spongy part of Yucca filifera stems for cushion filling.

3.2.7. Brushes and Brooms

The fibers of the Yucca genus, Agave lecheguilla, Nolina texana and Stipa robusta are used in the manufacture of these articles.

3.3. Timber

In the desert climate it is difficult to find timber-producing species for building and furniture. In some zones, especially mountainous ones, Pinus (11 species) and Quercus (49 species) are found. More frequently distributed are species such as Prosopis juliflora, Acacia greggii and Acacia farnesiana.

3.4. Resins and Waxes

Among the resin-producing species, Larrea tridentata stands out as the better known one and grows profusely in the Chihuahuan Desert. Other resin-producers are Schinus molle, Lantana camera, Solanum nigrum and Prosopis juliflora.

Another important vegetal product is wax, an epidermal secretion which covers the external organs and protects them from excessive water loss. Euphorbia antisyphilitica produces a hard wax which has many applications: as a substitute for Carnauba wax in floor polishes and candle manufacture; in various industrial applications such as printing and production of adhesives, celluloid, chewing gum, electrical insulation, cosmetics, crayons, shoes, furniture, paint remover, records and others. Other wax-containing species are Pseudotsuga taxifolia, Agave spp., Partenocissus quinquefolia, Aloe spp., Fouquieria splendens and CACTACEAE species.

3.5. Rubber and other Cellulosic Polymers

Parthenium argentatum, guayule, represents the major hydrocarbon-producing resource of the Chihuahuan Desert. Currently vehicle tires are being made from guayule rubber.

The Asclepias species also contain rubber but in small quantities.

Elymus canadensis, Phalaris canariensis and Euphorbia dentata also contain small quantities of polymeric hydrocarbons.

4. Food

The Chihuahuan Desert flora offer some nutritional possibilities, for direct consumption or on the basis of extractions to obtain oils and proteins to enrich food.

Also some animals can be reared using plants or their residues as fodder.

Vitamins, especially C, are often found in greater quantities than those of oranges. In this respect, Agave lecheguilla, Cersis canadensis, Opuntia ficus-indica, Stellaria media and Yucca elephantipes are important.

Minerals, such as K, Na, Ca, Mg, Fe and P, are abundant in the fruit juice of Opuntia; Carnegia gigantea contains K, Mg and Ca; Atriplex canescens ash contains K, Ca, Mg, P, Cu, Pb and trace elements; Triticum aestivum contains Ca, Mg, Mn and N and Prosopis juliflora shows a high content of P and N.

4.1. Fruits

A great quantity of fruit is consumed - fresh, dry or prepared. Some of them originate small industries, such as vinegar and flour production.

The species comprising this group are Opuntia spp., Myrtillocactus geometrizans, Vitis arizonica, Carnegia gigantea, Prosopis juliflora, Yucca spp., Acacia greggii, Arctostaphylos pungens, Lycium pallidum and Physalis spp.

4.2. Leaves and Stems

These organs are consumed raw or stewed. The leaves of Opuntia spp. contain vitamins, carbohydrates, protein, aminoacids and calcium and phosphorus salts. In the same way the leaves of Amaranthus spp., Atriplex spp., Chenopodium spp., Rumex crispus and Tradescantia spp. are consumed.

4.3. Seeds

4.3.1. Oils

Analyses carried out on seeds show that 150 species contain oil, the CRUCIFERAE family presenting the highest contents. Eruca sativa contains 32-36%, Lesquerella argyrae 27.4%, Lesquerella fendleri 28.1%. Cucurbita foetidissima shows a promising content of 30.4-33.95%.

4.3.2. Proteins

Chemical analyses carried out on plant seeds show that around 146 Chihuahuan Desert species contain proteins; four species also contain them in their leaves.

The family which contains the greatest quantity of proteins is LEGUMINOSAE and next is COMPOSITAE.

The aminoacid composition is known for 30 of the species which contain proteins in their seeds.

4.3.3. Carbohydrates

These substances are presented in plants in various forms. Starch occurs primarily in the seeds and its presence has been reported in 33 Chihuahuan Desert species.

Agave spp. contain fructose and inulin; Yucca spp. fructose, fructosanes, dilevanes and glucose; Opuntia ficus-indica pentose, manose and galactose and Prosopis juliflora pentosanes and galactanes as well as other carbohydrates.

4.4. Others

Species of the CACTACEAE, species of the Yucca genus and Prosopis juliflora supply raw material for honey bees. Opuntia spp., Carnegia gigantea and Agave atrovirens possess organs from which syrups are made.

Alcoholic drinks, such as "pulque", "tequila", "colonche" and "sotol" are prepared principally from Agave and Dasylirion.

4.5. Fodder

4.5.1. Green Plants

Abundant pasture is formed during spring and summer by 457 species of the GRAMINEAE family. Mesquite (Prosopis juliflora) is also good animal fodder but in great quantity produces malnutrition due to its high sucrose content which causes changes in the intestinal bacterial flora.

In periods of drought, it is possible to resort to various species of the Opuntia genus, using the leaves which have to be previously burnt to remove the thorns. The central stem and bases of the leaves of species of the Dasylirion genus, as well as the central parenchyme of Echinocactus visnaga can be used in emergency, as apart from supplying food they proportion drink due to their high water content. Other important species are Agave atrovirens and Acacia farnesiana.

4.5.2. Dry Plants

Various of the GRAMINEAE species can be dried and stored for use as fodder during autumn and winter when the pasture disappears.

4.5.3. Residues

The feasibility of using the following species as fodder has been studied:

Agave lecheguilla: after extracting the saponins and toxic substances, a residue of superior quality to hay remains.

Euphorbia antisyphilitica: the candelilla residues can be used as fodder in conjunction with supplements, after the wax-extraction process.

Larrea tridentata: the residue left after the resin extraction can be used as animal fodder. The nutritional value of this food is comparable to that of alfalfa due to the content of minerals, carotene, aminoacids and a high digestible protein content.

Yucca spp.: these residues can be used as fodder after the extraction of fibers and saponins.

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RESUMEN

La información escrita sobre la diversidad y cantidad de la flora en el Desierto Mexicano de Chihuahua justifica la creación de un Banco de Datos que al mismo tiempo que ayude en el estudio de la flora in situ, podría utilizarse para llevar a cabo programas de desarrollo en esta región marginada. En este trabajo se presentan la organización del Banco de Datos, metología de trabajo, especies, familias, los productos químicos presentes en la flora, y sus usos.

Digital Landsat and Terrain Data Applied to an Arid Land Resource Inventory[1]

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Wayne G. Rohde[4], and Lorin P. Schwartz[3]

Introduction

The U.S. Geological Survey's EROS Data Center (EDC), in cooperation with the Bureau of Land Management (BLM), evaluated the utility of digital data from Landsat, digital terrain data, and stratified-cluster sampling for mapping wildland vegetation in the arid and semi-arid region of Southwest United States. Large-scale aerial photographs and ground data were collected for use in the classification process and development of the final products.

The Landsat-derived vegetation classification was merged with digital terrain data (elevation, slope, and aspect) into a data base from which map overlays were developed showing the distribution of areas amenable to potential management practices.

Analysis Procedures

Digital data from Landsat (acquired August 26, 1977) and digital terrain data obtained through the National Cartographic and Information Center (NCIC) were geometrically corrected and registered to a common Universal Transverse Mercator projection using mapping transformations as described by Johnson (1978). The project boundary and BLM administrative units were plotted on 1:250,000-scale maps, digitized, and registered to the Landsat data. Only those Landsat picture elements that fell within the project area (1 million hectares) were used for all subsequent processing. A controlled clustering technique, similar to that described by Fleming and others (1975), and an unsupervised clustering technique, described by Rohde (1978), were used to cluster the Landsat digital data into 76 spectrally separate clusters.

The cluster statistics and Landsat data were entered into a maximum-likelihood classifier, and each pixel in the project area was assigned to the class to which it had the highest likelihood of belonging, based on its brightness value in all four Landsat MSS bands. After classification, each spectral cluster was considered a computer class. Each computer class was then systematically displayed on an interactive color monitor. From color-infrared aerial photographs and vegetation maps of selected areas, each computer class was assigned to one of nine land cover classes (seven wildland vegetation types, barren land, and agricultural land).

After the computer classes were aggregated to represent nine land cover classes, more quantifiable data were collected using a stratified-cluster sample procedure (Rohde and others, 1979). A total of 119 8-pixel by 8-line sample clusters were allocated proportional to stratum size. Cluster sampling was used because, once a plot is found, it is less expensive to locate adjacent plots that comprise the cluster. This method permits the sampling of more plots at a lower cost per plot. Sample clusters were plotted, and flight lines were then located on 1:24,000-scale topographic maps for acquiring 1:6,000-scale stereo color aerial photographs of each sample cluster (fig. 1).

Once the color photographs were acquired, the perimeter of each sample cluster was transferred onto 1:24,000-scale orthophoto quadrangles, and the four corner points of each cluster were manually transferred to the 1:6,000-scale color transparencies. Each sample cluster was then partitioned into 64 photo plots, each photo plot corresponding to approximately one Landsat picture element (0.4 hectare). Each photo plot was then interpreted on the color photographs using a vegetation classification framework developed for the project. A tabular comparison of Landsat classification results with the photo-interpreted data showed that confusion existed between computer classes and vegetation types within the project area.

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[1] Poster presentation at the Arid Lands Resource Inventories workshop, Nov. 30 - Dec. 6, 1980, La Paz, Mexico.

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[4] U.S. Geological Survey, EROS Data Center, Sioux Falls, South Dakota.

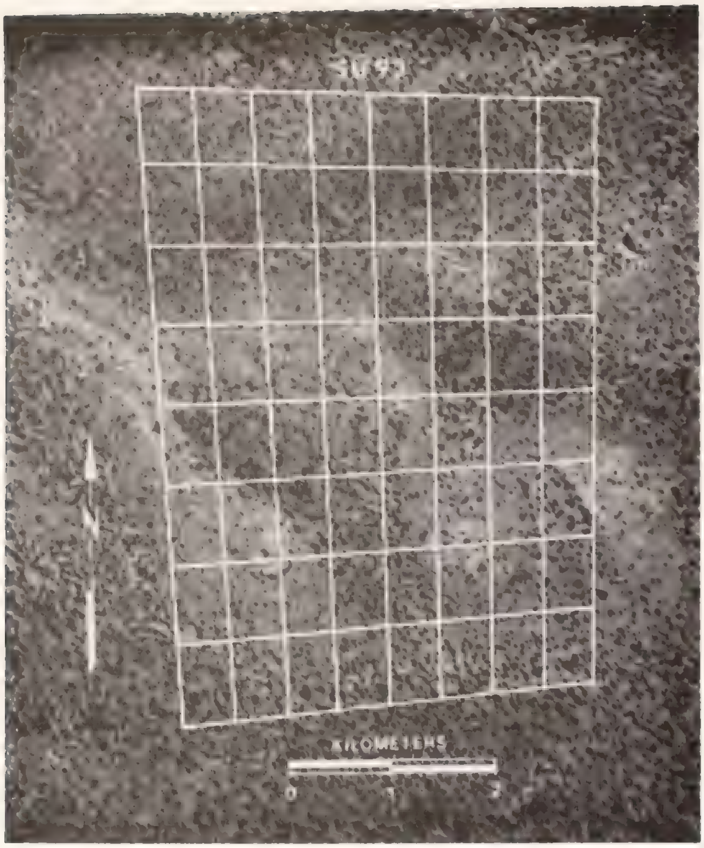

Figure 1. Black and white portion of a 1:6,000-scale color photograph showing a sample unit partitioned into 64 photo plots. The predominate vegetation type is Evergreen Woodland.

Table 1. Accuracy estimates for an aggregation of all computer classes into 8 representative cover types before and after using terrain data in the classification process.

COVER TYPE	ACCURACY			
	WITHOUT TERRAIN DATA		WITH TERRAIN DATA	
	CORRECT	STANDARD ERROR	CORRECT	STANDARD ERROR
Cropland/ Pasture	15%	17%	19%	23%
Coniferous Forest	72%	7%	81%	12%
Evergreen Woodland	77%	6%	81%	5%
Deciduous Woodland	4%	4%	70%	23%
Mohave Desert Shrub	74%	6%	96%	2%
Great Basin Desert Shrub	57%	4%	68%	4%
Mountain Shrub	38%	14%	58%	15%
Grassland	1%	1%	2%	1%
OVERALL	54%	5%	73%	5%

Post Classification Refinement

Previous studies have shown that Landsat misclassification could be minimized by using digital terrain data (Fleming and Hoffer, 1979). When the photointerpretation data were compared with the digital elevation data, meaningful vegetation/terrain relationships were identified. Using these relationships, BLM field personnel assisted in developing elevation decision rules for each of the 76 computer classes. All pixels in the entire project area were reclassified using a modified-parallelepiped classifier with specific elevation break points for each computer class. An estimate of the proportion of pixels correctly classified and the error associated with this estimate were calculated before and after using terrain data. By using terrain data, classification accuracy increased from 54% to 73% (Table 1). In these procedures, it is assumed that the photointerpretation is correct, and thus care must be taken when interpreting these results.

The photointerpretation data were also used to develop for each computer class a description indicating the proportion of each cover type associated with the class. The descriptions were made by comparing the photo-interpreted data with the corresponding computer classified data (Table 2). Such a description can also be developed for aggregations of computer classes.

Table 2. Cover type description for a representative computer class.

COVER TYPE DESCRIPTION BASED ON PHOTO DATA

Computer Class: 59

Total Photo Plots 120

Mohave desert shrub		Great Basin desert shrub	
Creosote	33%	Blackbrush-other desert shrub	2%
Bursage	28%		
Mixed desert shrub	37%		
Total	98%		2%

Project Cost

The overall cost for conducting this project was $0.15 per hectare. This figure includes direct labor, computer time, imagery and tape products, travel, outside photo acquisition contracts, and final map products.

Products

The most useful products obtained from the project were (1) the tables that describe the vegetation and terrain conditions within each of the Landsat spectral classes and (2) the digital data base containing the Landsat-derived vegetation data, elevation, slope, and aspect for each pixel within the project area. Because these data are in digital format, they can be quickly analyzed to produce information for use in the planning process. Typical applications include: (1) identification of potential zones for specific management activities, (2) areas where conflict in management practices may occur, or (3) areas where certain management actions may compliment one another.

For example, a specific management problem was locating potential Bighorn Desert Sheep habitat. Using criteria specified by BLM personnel, all pixels representing land that lies between 900 and 2,500 meters on slopes greater than 20% and that were associated primarily with Mohave desert, Great Basin desert, and mountain shrub were extracted from the data set. Using this data, a map overlay was produced showing the location of potential Bighorn Desert Sheep habitat in black (Fig. 2). Since the data base needed to produce this overlay already existed, this overlay was produced for a cost of $0.002 per hectare. It is important to remember, however, that this overlay only points out areas potentially suitable as Desert Bighorn Sheep habitat and thus should be used solely as a planning tool.

Figure 2. Map product showing potential Bighorn Desert Sheep habitat (in black).

Conclusion

On the basis of the results of this project, BLM has found this technology extremely useful in mapping and inventorying their lands. The results are consistent with those from similar projects conducted on other areas representative of BLM lands, especially in terms of: (1) similarity of cost ratios, (2) improvement in accuracy when terrain data were incorporated into the analysis procedure, (3) establishment of an economic sampling base, and (4) the creation of a digital data base from which overlays can be developed for examining management alternatives.

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RESUMEN

En base a los resultados de este proyecto, BLM ha encontrado esta tecnología de extrema utilidad en el inventario y cartografía de sus tierras. Los resultados son consistentes con los de otros proyectos similares conducidos en otras áreas representativas de tierras de BLM, especialmente en términos de: 1) similaridad de razón de costos, 2) mejora en la precisión con que la data de campo fué incorporada al proceso analítico, 3) establecimiento de una base económica de muestreo y 4) la creación de una base digital de data de la cual pueden desarrollarse perspectivas para estudiar las alternativas de administración.

Resource Data Analysis Systems — Moderator's Comments

James C. Space

Abstract.--Continuing developments in computer and communications technology, applications software, and data base management systems are providing increasingly powerful tools for the resource analyst. The challenge is to effectively incorporate these new methods into day-to-day operations to increase productivity and improve decision-making.

Technological advances continue to be made at a rapid rate in such areas as:

Integrated circuitry, permitting a very large number of components to be combined on a single silicon chip, increasing processing speeds while drastically reducing the cost of central processing units and high-speed memory.

Storage techniques, such as higher density tapes and disks as well as new technology just reaching the market such as bubble memory and laser-recorded disks and tapes.

Packet-switched communications which provides low-cost, reliable access to processing capacity, both nationally and internationally.

Generalized applications which the user can employ in many situations without the high costs of systems development and maintenance.

Data Base Management systems, permitting effective and efficient organization and processing of highly complex inter-relational data.

Very high level programming and query languages which allow the end user to easily develop his own applications and to summarize data in whatever form is desired with little or no advance specification.

Graphics systems for the processing and display of data in visual form, including map data as well as more traditional uses as business and design graphics.

Reliable, low-cost computing power is fast becoming available to individuals and organizations throughout the world, either in the form of mini-computers or over shared communications provided by the rapidly spreading public communications networks. This power allows rapid processing of data at low cost and, through the generalized systems and processors available on most general-purpose computers, permits analyses which would have been impossible only a few years ago. However, a number of problems still remain:

1. Technology takes time to spread from the developed countries to the less well developed countries even when it is available. Manufacturers tend to concentrate their initial sales in the largest markets since they can make a higher volume of sales and it is easier to maintain their products. Thus, it may be difficult to obtain adequate equipment, or an exorbitant price may be charged for providing and servicing equipment. The best hope of some countries may be to persuade their telecommunications authorities to provide a linkage to computer resources using packet-switching technology so that only a low-cost, reliable, easily maintained terminal is needed locally.

2. Skills have not kept pace with technology. This is a problem in the developed countries, but is a very serious problem in the lesser developed countries where the demand for skilled people far exceeds the supply. In many of these countries, the technology can easily be purchased, but it may be impossible to get people with the requisite skills. Training takes a long time; the skills are needed now. On the other hand, data processing can effectively extend the availability of skilled people by making them more productive.

3. Adoption of new methods invariably leads to organizational change. New jobs are required, while others become less important or are eliminated. People have to change their work habits. Unless handled carefully, surreptitious or active opposition to new techniques can easily develop.

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4. Management is often not aware of technological developments and is unprepared to cope with them. To be effective, managers must be actively involved in the decisions on the acquisition and use of new technology. Even in the United States, management has great difficulty in keeping abreast of new developments. We all tend to fear and oppose the unknown, and this can be a real barrier to adopting more effective techniques.

Thus, even though continuing technological developments have greatly lowered the cost and increased the effectiveness of processors and processing tools, many problems remain, especially those of a sociological nature. It is a challenge for all of us to adopt and utilize the technological tools which are available today, and to effectively incorporate them into our operations to increase productivity and to provide the information for improved decision-making at all organizational levels.

SISTEMAS DE ANALISIS DE DATOS DE RECURSOS

OBSERVACIONES DEL MODERADOR

James C. Space

Resumen.-- Los adelantos continuos en el campo de la tecnología de comunicaciones y de las computadoras, los programas para aplicaciones, y la administración de sistemas de bancos de datos proporcionan cada vez instrumentos más poderosos para el analista de recursos. El reto consiste en incorporar día a día, en forma efectiva, estos nuevos métodos en operaciones para aumentar la productividad y mejorar la toma de decisiones.

Se continúan haciendo adelantos tecnológicos a un paso acelerado en aquellas áreas como ser:

Circuitos integrados, permitiendo la combinación de un grán número de elementos en una brizna de silicio aislado, aumentando las velocidades de procesamiento mientras se reduce en forma drástica el costo de las unidades centrales de proceso y las memorias de alta velocidad.

Técnicas de almacenamiento, tales como cintas y discos de densidad superior así como nueva tecnología que recientemente ingresa al mercado, como memoria de "burbujas" y discos y cintas grabados con rayos laser.

Comunicaciones con paquetes de conmutación, que proveen acceso seguro, a bajo costo, a la capacidad de proceso, ya sea a nivel nacional o internacional.

Aplicaciones generalizadas, que el usuario puede emplear en muchas situaciones sin el costo elevado de desarrollo y mantenimiento de sistemas.

Sistemas de administración de bancos de datos, que permiten la organización y el procesamiento efectivo y eficiente de datos interrelacionados altamente complejos.

Programación de nivel muy elevado y lenguages de interrogación, que permiten que el usuario final desarrolle fácilmente sus propias aplicaciones y que haga un resumen de datos en la forma deseada ya sea con especificaciones muy pequeñas o avanzadas.

Sistemas gráficos, para el proceso y exhibición de datos en forma visual, incluyendo datos sobre mapas, así como empleando aplicaciones más tradicionales como gráficos de negocios y de diseño.

La disponibilidad de computación confiable, de bajo costo, se está generalizando rápidamente, para individuos y organizaciones en todo el mundo, ya sea en forma de mini-computadoras o de comunicaciones compartidas provistas por la rápida extensión de la red pública de comunicaciones. Esta capacidad permite el proceso rápido de datos, a bajo costo, y mediante los sistemas generalizados y unidades de proceso disponibles en la mayoría de las computadoras universales, permiten hacer análisis que hubieran sido imposibles hace algunos años. Sin embargo, todavía quedan un número de problemas por resolver:

1. La difusión de la tecnología de los países desarrollados a los menos desarrollados, aún cuando ésta está disponible, lleva tiempo. Los fabricantes tienden a concentrar sus ventas iniciales en los mercados más grandes ya que ellos pueden tener un mayor volumen de ventas y además es más fácil mantener sus productos.

Así, puede ser difícil obtener el equipo adecuado, o puede cobrarse un precio exhorbitante por proveer y mantener dicho equipo. La mejor esperanza para algunos países puede ser el persuadir a sus autoridades de telecomunicaciones para que provean una conección con los recursos de computación usando tecnología de paquetes de conmutación para que sólo sea necesario una terminal local de bajo costo, confiable y de fácil mantenimiento.

2. Las destrezas del personal que usa los equipos no se han mantenido al paso de la tecnología. Este es un problema en los países menos desarrollados donde la demanda por gente con destreza es mayor que la oferta. En muchos de estos países, la tecnología puede ser adquirida fácilmente, pero puede ser imposible conseguir gente con el adiestramiento necesario. Adiestrar gente toma mucho tiempo; y es hoy que se necesitan las destrezas. Por otra parte, el procesamiento de datos puede ampliar efectivamente la disponibilidad de gente capacitada, haciéndolos más productivos.

3. La adopción de nuevos métodos invariablemente lleva al cambio organizacional. Se requieren nuevos puestos de trabajo, mientras otros se convierten en menos importantes o son eliminados. La gente tiene que cambiar sus hábitos de trabajo. Se puede crear una oposición subrepticia o activa a las nuevas técnicas, a menos que se trate este asunto con cuidado.

Las empresas a menudo no se dan cuenta de los adelantos tecnológicos y no están preparadas para hacerles frente. Para ser efectivos, los gerentes de empresas deben estar activamente envueltos en las decisiones de adquisición y uso de nueva tecnología. Inclusive en los Estados Unidos, las empresas tienen gran dificultad para mantenerse al tanto de nuevos desarrollos en cuanto a tecnología. Todos tememos y nos oponemos a lo desconocido y esto puede ser una barrera grave en la adopción de técnicas más efectivas.

Así, aunque el desarrollo contínuo de tecnología ha bajado grandemente el costo y aumentado la efectividad de unidades de procesamiento y de instrumentos de proceso, muchos problemas subsisten, especialmente aquéllos de tipo sociológico. Es un reto para todos nosotros adoptar y utilizar los instrumentos tecnológicos que están disponibles hoy día e incorporarlos en forma efectiva en nuestras operaciones para aumentar la productividad y proveer la información para la mejor toma de decisiones en todos los niveles organizacionales.

Seccion IV. Proposición para el Intercambio de Investigación Científica sobre Zonas Aridas — Una Panorámica[1]

Section IV Proposals for Exchanging Research on Arid Lands — An Overview[1]

Ing. Manuel Enriquez Quintana[2]

En los albéres de la humanidad el hombre primitivo pudo subsistir y desarrollarse mediante la recolección de frutos y la - caza de animales silvestres, en virtud - de que su número era muy reducido y los- recursos naturales de que disponía muy - abundantes. En la medida que el hombre - se volvió sedentario, incrementó su re - producción y se culturizando, sintió la- necesidad de conocer y entender cada vez más los recursos naturales de los que podía obtener su alimento, su techo, su - vestido, susmedicinas y las armas que le daban seguridad; y poco a poco fué lle - gando a la domesticación, cultivo, cría- y fomento de las especies de su interés. Debido al islamiento en que vivían las - comunidades primitivas, la humanidad tuvo que emplear muchos años aprendiendo - cuales recursos eran mejor que otros para la satisfacción de sus necesidades y- la falta de comunicación originó que t-- también se tuviera que invertir mucho - tiempo observando fenómenos semejantes , es decir, que hubo necesidad de efectuar simultáneamente o repetir las mismas experiencias.

Al irse desarrolla ndo y mejorando los - medios de transporte y de comunicación,- las comunidades primitivas tuvieron la - oportunidad de iniciar el contacto con - otras comunidades y de esa manera empe - zar a intercambiar experiencias; y al conocer la forma que como otras comunida - des encaraban y resolvían sus problemas- empezaron a estar en posibilidades de evitar invertir esfuerzos innecesarios y a - evitar perder el tiempo repitiendo desde- el principio lo que ya estaba hecho.

Es importante el preguntarnos cuantas veces muchos de nosotros hemos procedido como el hombre primitivo, trabajando en forma aislada, descoordinada y repitiendo investigaciones sobre temas que ya habían sido resultos, a pesar de que, a diferencia del hombre primitivo, nosotros disponemos de los grandes adelantos de la ciencia y- la tecnología en materia de comunicación- y transportes que por falta de visión, ,- falta de solaridad humana o pereza evitamos emplear. Es inconsebible que en la - época de los satélites; del radar; de las computadoras y sus terminales; del telex; del teletipo ; de la televisióm, del teléfono, telégrafo; las fotocopiadoras; los microfilms; las grabadoras; la imprenta; los aviones supersónicos; cuando el hombre ya llegó a la luna y cuenta con equipos e instrumentos para estudiar el fondo de los mares; todavía se presenten con frecuencia los casos de duplicación de investigacio - nes con la consecuente pérdida de tiempo,- dinero y esfuerzos.

de acuerdo con las cifras reportadas por - las Naciones Unidas, para el año de 1973 - la población del mundo era del orden de - 4,119 millones de habitantes y se predecía que para el año 2,000 se alcanzará la cifra de 6,253 millones de habitantes, es decir, que habrá 2,134 millones de habitantes más, que incidirán sobre los recursos naturales y demandarán que se les satisfagan sus necesidades de alimento, vivienda, vestido, salud pública, educación recreo, etc.

El continente Americano en 1973 contaba con 467.1 millones de habitantes, de los cuales 249.6 millones vivían en Estados Unidos y - Canadá; y los 217.5 millones restantes en los países de América Latina. En esta última región se requiere con mayor urgencia- efectuar el aprovechamiento racional de -

[1] Trabajo presentado en el Evento Internacional, "Inventarios de Recursos de Zonas Aridas", La Paz, B.C.S., México, Nov. 30-Dic. 6, 1980.

[2] Asesor, Coordinación de Proyectos de Desarrollo de la Presidencia de la República.

3.- Instituto Nacional de Investigaciones Forestales (INIF)
Durante la presente administración esta- Institución elevó esta categoría de centros Regionales de investigación los campos experimentales que tenía en la Saucedа Cohauila y Todos Santos, B.C.Sur. -- Tambien creó un Departamento a nivel nacional para investigar sobre evaluación- de recursos forestales.
4.- Instituto Nacional de Investigaciones Agrícolas (INIA)
5.- Instituto Nacional de Investigaciones Pecuarias (INIP)
6.- Instituto de Investigación de Zonas - Desérticas de la Universidad Autónoma de San Luis Potosí, S.L.P.
7.- Instituto Nacional de Investigación de Recursos Bióticos (INIREB).
8.- Instituto de Ecología . A.C.
9.- Centro de Investigación de Quimíca - Aplicada (CIQA)
10.- Centro de Investigaciones Científicas y Técnicas de la Universidad de Sonora (CICTUS)
11.- Laboratorios Nacionales de Fomento INdustrial(LANFI)
12.- Centro de Investigaciones del Desarrollo Rural (CIDER)
13.- Centro de Investigaciones Agrarías - (CIA)
14.- Colegio de Postgraduados de Chapingo (C.P.)
15.- Universidad Agraría Autónoma Antonio Narro.
16.- Universidad del Estado de Nuevo León
17.- Instituto Tecnológico de Monterrey
18.- Universidad del Estado de Chihuahua.
19.- Universidad del Estado de Durango.
20.- Universidad del Estado de Zacatecas.
21.- Universidad del Estado de B.C. Norte
22.- Universidad del Estado de B.C. Sur
23.- Universidad del Estado de Querétaro
24.- Universidad del Estado de Guanajuato
25.- Universidad Autónoma de Chapingo
26.- Universidad Metropolitana
27.- Universidad Iberoamericana
28.- Escuela Normal del Desierto
29.- Universidad Nacional Autónmoma de - México (UNAM)
30.- Instituto Politécnico Nacional(IPN)
31.- Dirección de Estudios del Territorio Nacional (DETENAL)
32.- Dirección General del Inventario Nacional Forestál
33.- Dirección de Reforestación y Manejo de suelos forestales.
34.- Comisión Técnica Consultiva para la Determinación Regional de los Coeficientes de Agostadero (COTECOCA)
35.- La Forestal F.C.L.
36.- Plan Nacional de Areas de Temporal (PLANAT)
37.- Comisión Coordinadora para las Areas Marginadas (COPLAMAR)
38.- Programa Integral de Desarrollo Rural (PIDER)
39.- Fondo Nacional de Fomento Ejidal
40.- Banco Nacional de Comercio Exterior
41.- Banco Nacional de Crédito Rural
42.- Fideicomiso de Apoyo a la Agroindustria
43.- Comisión Nacional de Fruticultura (CONAFRUT)
44.- Instituto Nacional de Desarrollo de la Comunidad (INDECO).

La Secretaría de Educación Pública, -- tambien ha instalado diversas escuelas - de nivel medio básico y de nivel medio - superior, teniendo noticias de que en - breve el INIF instalará una escuela de- técnicos forestales de nivel medio superior en Saltillo, Coah.
También con el apoyo del gobierno federal y de los gobiernos estatales, se ha recibido la colaboración de organismos internacionales como la FAO, UNESCO, ONUDI, y de instituciones de los Estados Unidos como- la Universidad de Arizona, la Universidad de Fort Collins, Colorado y el Museo del- Desierto Arizona-Sonora.
México ha enviado profesionales a países como Israel, Australia, Chile, Argentina, U.S.A., etc. con el objeto de conocer como vienen estudiando y resolviendo los -- problemas de las zonas áridas.
Como puede verse el esfuerzo desplegado - por el Gobierno de México es más que ra - cionable; sin embargo, debemos reconocer- que los resultados obtenidos hasta la fecha son modestos si se comparan contra el tremendo esfuerzo realizado y la asiganación de recursos efectuados. Cabe entoncés preguntarnos cuales han sido los obstáculos- que han impedido avanzar más aprisa en la solución de los problemas?. Seguramente - son varios y de diferente índole, sin - embargo, deseo apuntar que desde mi personal punto de vista son tres los principales obstáculos :
1.- La carencia de un plan de acción a - largo plazo que encuadre las acciones a - mediano y corto plazo, y permita seleccio

nar con sentido realista las estrategias a seguir, fijar las metas a lograr, programar las actividades a realizar, definir las inversiones que se mecesitan efectuar y evaluar los resultados obtenidos.
2.- La mínima coordinación existente entre los centros de Enseñanza e Investigación entre sí, y de éstos con las INstituciones operativas, lo que ha propiciado - la duplicación de trabajos, la generación de resultados que no se aplican en la -- práctica, la dispersión de esfuerzos y recursos, la interferencia de acciones porcelos profesionales e institucionales; el ocultamiento de información y de resultados, en lugar de buscar una distribución- o complementación de las acciones y una - retroalimentación constante entre las -- Areas de enseñanza e investigación con el área operativa .
3.- La falta de recursos humanos debidamente preparados en todos los niveles, - tanto en el area de enseñanza e investigación como en el area operativa.

Para ilustrar un poco lo anterior, mencionaremos que de acuerdo al ATLAS denominado uso del suelo en la República Mexicana, editado por la SARH en 1979, las zonas -- áridas cubren una superficie de 82 millones de hectáreas con la siguiente distribución:

No.	USO DEL SUELO		SUPERFICIE (Millones Ha.)
1	Matorral	inerme	7.8
2	"	Subinerme	19.3
3	"	Espinoso	12.4
4	"	Subespinoso	11.2
5	"	Crasirosulifolio	10.5
6	Mezquital		1.0
7	Chaparral		3.9
8	Vegetación halófita		2.0
9	Izotal		1.0
10	Nopalera		1.6
11	Cardonal		2.3
		TOTAL	82.0

Por otra parte la edición especial de la revista México y sus Bosques!, publicada en Agosto de 1970 incluye una relación de las superficies forestales de clima templado y frio; cálido húmedo y zonas áridas y semiáridas, reportando para éstas últimas la cifra de 54.1 millones de hectáreas. Es oportuno hacer la aclaración que dicha relación de superficies se atribuye a la Subsecretaría Forestal y de la Pauna que depende de la SARH .

No.	USO DEL SUELO	SUPERFICIE (Millones Ha)
1	Mezquitales	6.7
2	Matorral rosetofilo	1.2
3	Matorral microfilo	34.0
4	Matorral Crasicaule	11.1
5	Areas perturbadas	1.1
	TOTAL	54.1

Como puede observarse en los datos anteriores, no concuerdan los nombres usados- para clasificar la vegetación ní las cifras de la superficie reportadas y ambos- trabajos corresponden a una misma Institución . Hoy en la mañana hemos escuchado - también las cifras de 56 y 74.3 millones- de hectáreas como superficie de las zonas áridas; lo que pone de manifiesto que a - pesar de contar con 44 Instituciones que- de alguna forma trabajan en éstas áreas,- todavía a estas alturas no tenemos una cifra confiable.
Por lo antes expuesto, es que deseo aprovechar esta oportunidad para exortar a todos los asistentes a esta Reunión sobre - Inventario de Recursos de Zonas Aridas, - para que no procedamos como el hombre primitivo que tuvo que trabajar aislado obligadamente por carecer de toda la infraestructura de comunicación y transporte que ahora podemos usar. Debemos tener presente que nuestra generación no cuenta ahora con la abundancia de recursos naturales - que hubo en el pasado y por lo mismo debemos sumar esfuerzos en la búsqueda de soluciones a los problemas que enfrenta la humanidad; de ahí que pensemos en la necesidad de incrementar la comunicación - entre los investigadores; la realización de proyectos de investigación donde participe personal de diferentes disciplinas - de la ciencia, de diferentes institucio - nes y diferentes nacionalidades, bajo la dirección de un solo organismo que bien- podría ser la Subsecretaría Forestal y de la Fauna, CONAZA ó CONACYT, pués de acuerdo con la Ley Forestal en vigor corresponde a la Subsecretaría Forestal atender - lo referente a toda la vegetación espontanea que existe en las zonas áridas y - también existe un decreto Presidencial - que le señala a CONAZA la obligación de coordinar todas las acciones en estas - áreas. CONACYT por su parte tiene el compromiso de coordinar toda la investiga - ción en México. De no ponerse de acuerdo

todos los recursos naturales y desde luego de los correspondientes a las zonas semiáridas, pués sus índices de crecimiento demográfico, de analfabetismo, de desempleo, salud pública, falta de vivienda en verdad son alarmantes constrastando con los altos niveles de vida de que actualmente disfruta la población de Canadá y Estados Unidos, previéndose la continuación de estallidos sociales de consideración en los países de América Latina como consecuencia de la agudización de la demanda de bienes y servicios semejantes a los que diariamente le son mostrados y exaltados a sus habitantes por los medios masivos de comunicación como la televisión, el cine, la radio, la prensa y las revistas. Es por ello que los centros de enseñanza, de investigación y capacitación de América Latina tienen frente a sí el grave compromiso de no perder el tiempo y redoblar sus esfuerzos por estudiar y encontrarle aplicación a los recursos naturales entre los que se cuentan las zonas semiáridas.

Para el caso de México, la situación que se espera para el año 2,000 es poco alagadora e impone la necesidad de trabajar con renovado entusiasmo y en intima vinculación entre los centros de enseñanza, de investigación y capacitación con las Instituciones operativas, pués de acuerdo con los cálculos más optimistas del Consejo Nacional de Población que consideró de reducción gradual de la taza de crecimiento anual con cifras del 2.5% para 1982 hasta bajar al 2%; para el año 2,000 se tendrán 105 millones de habitantes, es decir, 37 millones de mexicanos más que los reportados en 1980 y que sin lugar a dudas nos obligarán a utilizar mejor los recursos naturales.

Con el propósito de dimensionar el reto que tenemos enfrente la generación actual de mexicanos, es conveniente mencionar que una población de 37 millones de habitantes equivale a toda la población de un país como España, o bién a la de Canadá o Australia juntos. De mantenerse el mismo índice de nacimientos habrá la necesidad de construir de 7 a 8 millones de nuevas viviendas, sin considerar el déficit de 5 millones que venimos arrastrando; habrán de crearse 20 millones, nuevos empleos preferentemente en provincia para que arraigen a la población, ya que de lo contrario la ciudad de México será una aglomeración de 35 millones de habitantes; la producción de maíz deberá de pasar de 11 millones de toneladas a 21 millones de Tons, es decir, prácticamente tendrá que duplicarse en el ámbito forestal deberemos dejar de ser importadores tradicionales de celulosa, de papel y de lápices si queremos que se cumplan con los progrmas educativos; deberemos mantener el crecimiento del producto interno a una taza no menor del 8% pero sin llegar a convertirnos en un país monoexportador de petróleo ya que correríamos el riesgo de seguir la misma suerte que Venezuela, Irán y Los emiratos árabes que están agotando sus reservas petroleras y sus pueblos continuan viviendo en la miseria y en la ignorancia.

Es importante destacar que el Presidente de México, Lic. José López Portillo, ha expresado públicamente su deseo de que una parte considerable de los excedentes de la venta del petroleo al extranjero, se orientan a los centros de enseñanza e investigación científica, lo cual debe ser un fuerte estímulo para quienes están decicados a esta actividad. De igual manera, es conveniente mencionar que a lo largo de varias administraciones del Gobierno de México a mostrado su interés por resolver los problemas de las zonas semiáridas y por lo mismo a visto con simpatía y ha apoyado la creación y funcionamiento de varias institutciones que participen en los 82,000 Km2 de las zonas semi-áridas[1] de las cuales podemos citar entre otras a las siguientes:

1.- Comisión Nacional de Zonas Aridas(CONAZA) Esta Institución ha promovido algunos trabajos de investigación sobre el uso industrial de la vegetación de zonas áridas, contando a la fecha con una planta piloto para producir hule de Guayule en Saltillo, Coah.; una planta para extraer aceite de la semilla de Jojoba en Ensenada, B.C. Norte y con los Laboratorios Nacionales de Fomento Industrial, están investigando los usos del fruto de la Yucca.

2.- Consejo Nacional de Ciencia y Tecnología(CONACYT).

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[1]Dato del Atlas: Uso del suelo en la República Mexicana. SARH.1979.

estas Instituciones, entoncés se debería acudir a los Organismos Internacionales-como la FAO para coordinar las acciones-en una primera etapa.
También se propone el intercambio de personal técnico entre los Centros de Investigación y Enseñanza tanto para estudiar como para prácticar los nuevos métodos - de trabajo; el envío de expertos a países menos avanzados para que asesoren en aspectos específicos; intercambio de publicaciones; intercambio de la relación de - proyectos de investigación en marcha y - en perspectiva para formar un Banco de - Proyectos; incremento de Reuniones semejante a la presente, etc.
En la medida en que trabajemos juntos estaremos cada vez más cerca de solucionar los problemas de las zonas áridas. No - tengamos temor a trabajar en grupos interdisciplinarios, ní en grupos interinstitucionales ní en grupos internacionales, - pués ya pasó la época en que una sola persona podía tener la solución de problemas que requieren el concurso de varias disciplinas de la ciencia y cada uno de nosotros tiene un cierto grado de conocimiento teórico, práctico, técnico, económico, político, social y cultural que aportar.

El reto para nuestra generación es grande, pero lo vamos a ganar, porque no podemos-defraudar a los niños y a los jóvenes que vivirán en el año 2,000.

Antes de concluir este presentación, deseo dejar un testimonio de reconocimiento a compañeros que han sido pioneros en México en la investigación de los Recursos - de Zonas Aridas:
Jersy Rendowsky; Efraín Hernández X.; - Jorge Marroquín, Fernando Medellín, Francisco Takaki, Robertino Velázquez, Javier Madrigal, Gustavo Borja , José Angel de - la Cruz, Lorenzo J. Maldonado, Marcelino Zapian, Fiacro Martínez, Heriberto Parra- y otros que demomento escapan a mi memoria pero que gracias a su tesón y a su incanzable sacrificio han mantenido vigente la necesidad de investigar los Recursos - de las Zonas Aridas.

Research Needs for Arid Land Resource Inventories[1]

Jay M. Hughes[2]

Abstract.--Arid lands represent a unique opportunity to improve inventory design and procedures. They are yet relatively uninventoried and unexploited. Experiences elsewhere in the more humid regions provide a foundation upon which to build.

Research needs follow information needs and include improvement in resource classification methods, cost minimizing data acquisition methods, and improved methods for data management which facilitate assessments of the effects of alternative levels and kinds of resource use.

INTRODUCTION

Somewhat more than 35 percent of the world's land area has been classified as "dry land" ranging in condition from semiarid to extremely arid (Walton, 1969). These are relatively inhospitable lands for human habitation; yet they are increasingly turned to for human settlement as their resources become more fully exploited and as a growing world population reaches out for new land and space in which to live.

Unfortunately, arid lands, in many ways, are fragile lands. Plant and animal life, while adapted to this environment, tend to recover from disturbance slowly and probably require more resources per unit of biomass recovered to restore than efforts in the more humid areas of the world. Thus, arid lands "management" must be "cost-efficient" management. Further, because of the often low value of arid land resources (excluding, of course, such resources as water, oil and gas, precious minerals, etc.) and large expanses of land involved, inventory costs per unit of resource information can be high.

In most respects, however, inventory design for arid lands must respond to the same design questions that are posed for designing inventories elsewhere. These questions include:

- What information is needed?
- How precise should the information be?
- How frequently is the information needed?
- How much information can be afforded?

These questions are embodied in the design of this conference and in many of the papers presented.

This paper, however, has as its objective the discussion of research needs for arid land inventories. This discussion is based upon the response of many of the participants in this conference to a pre-conference questionnaire survey. This survey asked each participating author to name and describe the single most important research need as perceived by the author within the context of his or her paper. These and other suggestions are organized by conference panel.

RESEARCH NEEDS

General

Recently, the National Science Foundation of the United States estimated that it had funded $32.5 million of arid and semiarid land research over the 1974-1978 Fiscal Year period (National Science Foundation, 1979). The major subject category of research, accounting for half of the total funds, was ecosystem research. Essentially none of this research dealt directly with resource inventory. Nevertheless, it does point up the fact that considerable research dealing with fundamental characteristics and use of arid land resources has been undertaken. This research, in turn, has implications for inventory research.

"Desertification" is a current, coalescing term encompassing research and application programs dealing with arid lands in the United States and with collaborative programs with the Republic of Mexico. This appears to be a useful prototype for activities, especially international activities, which deal with arid lands. Desertification has been defined as:

> ". . . the sustained decline and/or destruction of the biological productivity of arid and semiarid lands caused by man-made stresses sometimes in conjunction

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with natural extreme events. Such stresses, if continued or unchecked, over the long-term may lead to ecological degradation and utimately to desert-like conditions." (U. S. Department of the Interior, 1980)

Inventory and monitoring are two major areas of need identified in a recent study of desertification issues (U. S. Department of the Interior, 1980).

The papers presented at this conference are, in a sense, an inventory of research conducted, in part, in arid regions and with a strong emphasis on inventory methods. These papers, too, represent a substantial amount of research efforts devoted to arid lands.

A Need for Coordination

Running throughout the various sections of this conference in the responses of participants to the pre-conference survey was recognition of a substantial level of arid land research and inventory activity, and an equally substantial lack of coordination. Coordination needs seen include general and specific resource and resource use classifications to guide hierarchical data systems development. Some agreement on measurement and sampling standards was also suggested so that data from different countries and agencies might be combined with some known degree of precision.

There are concomitant needs for research associated with effective coordination of this type. These include broad spectrum preliminary measurements, or estimates, of expected variation within population attributes of interest. This would also probably include some kind of vigorous development of "significant" parameters which would be incorporated in "coordinated" inventory data bases. Some have proposed research dealing with prospective "demand" or prospective use of resources in order to focus attention on areas of increasing stress. Such research would employ state-of-the-art technology in mapping, computer graphics, remote sensing and socio-demographic projection.

Information Needs

Answering the question: "Who wants to know what, at what precision levels, and for what purpose?" is a necessary first step in designing an inventory. This question was embodied in research need assessment for arid land resource planning.

Interestingly, a key problem revealed by pre-conference responses related to determining the most effective means for inventorying multiple attribute systems. One respondent suggested that "ecosystem inventories" be implemented, implying that the resource itself is integrated and that quantitative ecology is the appropriate background discipline of the inventory specialist. Another respondent, on the other hand, argues for improved multidiscipline team processes to conduct "one-time" field inventories. Clearly needed, it seems, is a basic process for determining information needs.

Other research needs identified under this heading included determination of spatial and temporal distribution of precipitation and its effect on the environment and evaluation of alternative possible wildlife repopulation centers in northern Mexico.

Inventory Problems

Lack of coordination was referred to as a special and pervasive inventory problem. Measurement of rates of change in resource attributes was cited as an important means of assessing inventory need. Estimates of benefits and costs associated with inventories also were recommended to guide inventory intensity and frequency.

The logistical problems of conducting inventories in tropical areas give some indication of related research needs for arid land inventories. Tests of alternative remote sensing systems are recommended to determine resolution requirements for arid land resources in different areas and to minimize costs of data acquisition. Theoretical statistical sampling analyses should also be conducted prior to initiating inventories. Tests of extrapolating information from accessible to inaccessible areas are needed.

Inventory Planning

A major topic returned to by respondents to the pre-conference survey was the need for clear statements of the information requirements to be served by inventory activity. Suggested as a major need was research on methodology which can be used by administrators or managers for identifying information needs in several dimensions. This would include the development of analytical techniques for distinguishing between real "needs" and more trivial "wants"; development of quantification procedures for "requirements"; and development of a process for specifying constraints and choosing among alternative designs based on specific objective functions, such as minimizing cost.

More specific research suggestions included field testing and demonstration of the "Recreation Opportunity Spectrum" system for arid land recreation inventories; assessment of runoff and erosion rates in arid lands; identification and characterization of potential new crops from the sonoran desert; and investigation of spatial and temporal heterogeneity of arid lands based on a widespread ecological sample.

Land Classification

Again, a plea was made for a rational, consistent general system of resource classification using some systematic ecological basis. It was proposed that such a system should lend itself to

a variety of purposes and interpretations. Standardization of measurement procedures and interpretation rules were also suggested. Water resources were cited as a special area of need and an exceptional area for international collaboration. Vegetation sampling in conjunction with assessment of associated environmental factors was also suggested as a research need in order to better explain the distribution of plant species.

Economical Mapping and Remote Sensing Systems

Much research and development activity has occurred in remote sensing over the past 15 years or so, and arid land inventories are already incorporating the results of this activity. Coupling remote sensing technology with computerized digital analysis systems and computer graphic techniques represents an approach with great promise for reducing inventory costs. Again, however, information needs must be assessed before appropriate, more advanced imagery interpretation and data analysis systems can be designed for arid lands.

At this stage of technology development, many different platform/sensor/computer combinations are possible. It has been suggested in pre-conference response that an important area of need is systematic assessment of technical capability on an international scale so that available options can be better understood and evaluated. Such an assessment, coupled with specific information needs assessments for arid lands, would provide an effective starting place for further development of arid land mapping and remote sensing systems.

Cost Efficient Sampling Schemes

Resource inventories are characteristically sample-based. In spite of long and well-developed sampling traditions, there is still much to do to develop appropriate sampling schemes for arid lands according to pre-conference responses. Land use sampling systems are still evolving in natural resource inventories and require special emphasis for arid lands; sampling vegetation biomass efficiently in order to measure both current production and change over time requires adaptation to specified arid land conditions; and further development is needed of methods which permit cost minimization for the total inventory but measurements of several resources and their attributes simultaneously.

And as if on a broken record, the information needs refrain was played again. In this context, it was suggested that studies be undertaken to assess socio-cultural value systems associated with uses of arid land resources. This analysis could be used to sharpen perceptions of arid land resource information needs.

Efficient Field Measurement Techniques

Inventory specialists can claim special virtuosity in creating innovative and efficient field measurement techniques. The incentives are apparent to those experienced in field inventories because field costs are especially killing costs. Proposals for research in this area ranged from the very general to the very specific and included:

- Development of more general mathematical methods for estimating arid land vegetation cover;
- Development of generalizable means of estimating phytomass and its utilization as opposed to site-specific equations which are not extrapolatable;
- Refinement of fecal analysis techniques for estimating long-term trends in vegetative composition;
- Development of efficient methods for measuring salinity change over time;
- Improving the efficiency of measurement of tree size using optical dendrometers.

Resource Data Analysis Systems

Generally, three categories of research needs were identified in the pre-conference survey:

- Development of more efficient computer-based information handling systems;
- Development of useful multiple use management information sets for various levels of administration and geographic aggregation;
- Development of specific information categories and associated data acquisition and retrieval systems for specific purposes; e.g., for fuelwood.

Most of the suggestions for research in this area were focused on data classification, coding, storage and display systems. Yet, as the papers presented at the symposium suggest, there is much yet to be done in analytical systems development. Again, of course, data requirements must first be known in order to determine the relative worthwhileness of alternative systems which have different levels of cost and sophistication.

OVERVIEW AND SUMMARY

The experiences of those who have studied arid lands and those who have worked in the field of resource inventory are a rich source of suggestions for needed research on arid land inventories. If any one thing stands out, it is that because of the widespread community of interest among nations in arid lands and the unevenness of distribution of expertise in arid land inventories, an international effort is needed to organize effective arid lands inventory research activities. Hopefully, this workshop/conference can be used as a stepping stone to a more cohesive approach, on an international basis, to develop more efficient

ways to inventory arid lands. Sharing of experiences at this forum is useful; but now some new international initiatives should be taken to array our mutual capabilities more effectively around specific research targets.

Finally, while it is clear that an enormous capability for inventory design exists, it is equally clear that this capability will simply thrash about in frustration without direction. Specific resource information requirements must be established before our capacity for design can be creatively useful. Again, some international initiatives seem called for to pool our knowledge and assessments of arid lands information needs. Perhaps the desertification program can be used as a vector.

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SUMARIO

Las tierras áridas representan una única oportunidad para mejorar nuestros procedimientos y nuestros métodos inventivos. Están aun relativamente sin explotar, y sus riquezas sin inventariar. Las experiencias obtenidas en otras partes, en regiones más húmedas, proveerán una base sobre la cual poner los cimientos.

Las investigaciones necesitan seguir la necesidad de la información misma e incluyen ellas el mejoramiento de métodos de clasificación de recursos, reducción de costos de métodos adquisitivos de informacion y metodos mejorados del manejo de data , lo que facilita la evaluación de los efectos de niveles alternativos y diferentes formas del uso de los recursos.

Claramente, es necesaria la cooperación internacional en a los menos dos áreas, para así hacer una evaluación (un inventario) de las las tierras áridas en forma más eficiente. Primero, se deben desarrollar requisitos específicos en lo tocante a la información, para estas tierras áridas. Y segundo, se deben identificar los objectivos específicos, dentro del campo de los requisitos informativos ya convenidos mutuamente.

La Visita al Campo Experimental Forestal Todos Santos — Una Panorámica[1]

The Field Trip to Todos Santos Experimental Forest — An Overview[1]

Ing. Heriberto Parra Hake[2]

INTRODUCCION

Con la finalidad de que conozcan el medio ambiente de la región y con el propósito de ver directamente en el campo algunos trabajos de investigación en zonas áridas, los organizadores de este evento han programado una visita técnica al Campo Experimental Forestal Todos Santos dependiente del Centro de Investigaciones Forestales del Noroeste, para el próximo miércoles 3 de diciembre.

ANTECEDENTES

México ocupa aproximadamente una superficie de 2 millones de Km2, presentándose condiciones de aridez y semiaridez en 800,000 Km2 que presentan el 40% del territorio nacional y donde viven aproximadamente 10 millones de personas que representan un 16% de la población de la República.

Ante esta problemática, el Instituto Nacional de Investigaciones realiza estudios tendientes a desarrollar metodologías para aprovechar de una manera racional los recursos forestales de las zonas áridas y semiáridas, al través de 3 de sus 8 Centros Regionales de Investigación en el país. Estos son el Centro de Investigaciones Forestales del Noroeste con sede en La Paz, B.C.S., el Centro de Investigaciones Forestales del Norte con sede en Chihuahua, Chihuahua y el Centro de Investigaciones Forestales del Noreste con sede en Saltillo, Coahuila.

EL CENTRO DE INVESTIGACIONES FORESTALES DEL NOROESTE

El objetivo del C.I.F.N.O., es encontrar las mejores técnicas y metodologías enfocadas al manejo, aprovechamiento y conservación de los recursos forestales que al desarrollo socioeconómico de la región noroeste del país, que en su mayor parte se refiere a zonas áridas y semiáridas.

Para lograr tal objetivo, se desarrollan actualmente 4 proyectos de investigación:

1.- Uso múltiple de recursos naturales no maderables. Subproyestos:
   a) Catálogo de especies útiles.
   b) Manejo de especies útiles.
   c) Domesticación y aprovechamiento de especies útiles.

2.- Protección Forestal.
   a) Sanidad Forestal.
   b) Especies amenazadoras.

3.- Evaluación de recursos forestales.

4.- Establecimiento y manejo de plantaciones comerciales.

A la fecha éstos trabajos se realizan en el Campo Experimental Forestal Todos Santos, B.C.S. y la Residencia de Ensenada, B.C.

LA VISITA TECNICA

El Campo Experimental Forestal inició sus actividades en el mes de Agosto de 1971 y cuenta con una superficie de 1,000 Hectáreas. Se localiza hacia el suroeste de la Península de Baja California. La situación geográfica es de 110° 11' de longitud Oeste y 23° de latitud Norte. Se encuentra a 5 Kms. sobre la carretera Todos Santos-Pescadero, en un lugar denominado San Pedrito, Delegación de Todos Santos, Municipio de La Paz, B.C.S.

Oportunamente hemos entregado a ustedes un folleto que incluye un marco de referencia del Campo Experimental con información sobre Geología, topografía, hidrología, clima, suelos y vegetación, así como el texto de las ponencias que serán presentadas a lo largo del recorrido.

De una manera breve daré a ustedes una reseña del recorrido antes mencionado:

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[1]Trabajo presentado en el Evento Internacional, "Inventarios de Recursos de Zonas Aridas", La Paz, Mexico, Nov. 30 - Dic. 6, 1980.

[2]Director, Centro de Investigaciones Forestales del Noroeste, I.N.I.F, Mexico.

Estación No. 1

En esta estación ubicada en las oficinas del Campo Experimental, se dará la bienvenida a los participantes, se expondrán los objetivos y proyectos del --- C.I.F.N.O., así como un marco de referencia del Campo Experimental.

Estación No. 2

Diagnostico Ecológico de Poblaciones de Jojoba en el Campo Experimental Forestal "Todos Santos", B.C.S.
G.T.F. Salvador Fonseca Vera

En este trabajo se estableció un -- muestreo considerando todas las variables presentadas en el área de estudio como -- son la fisiografía, exposición, relieve, tipo de suelo y vegetación asociada.

Los sitios se ubicaron de la siguiente manera: Se buscó un punto que reuniera todas las características diferentes - posibles, este sitio fué ubicado en la -- punta del cerro de la capilla partiendo - de este sitio con respecto a la orientación de los puntos cardinales se establecieron los sitios de muestreo donde se -- realizaron tomas de datos.

Esta toma de datos se realizó en 32 sitios de muestreo de los cuales sólo en 12 de ellos, se detectó la presencia de - jojoba y de éstos la mayor parte en el elemento fisiográfico, planicie y ladera, con respecto a la exposición se detectó - claramente que en la totalidad de los sitios donde se encontró jojoba, se encuentran expuestos a los vientos predominantes del Noroeste. El análisis físico-químico comparativo de las muestras de suelo obtenidas de los sitios, se aprecia que - hay una predominancia grupo textural areno-limoso, el pH varió de 7.5 a 8.1.

De acuerdo a los datos obtenidos, se infiere que factores como suelos y exposición, fueron las características más importantes en la distribuición de la jojoba en el área de estudio; por otra parte, se evidencía la necesidad de profundizar los estudios ecológicos para conocer las condiciones preferentes que sigue la jojoba en su habitat y considerarlos como elementos básicos del conocimiento sobre la especie a fín de normar los criterios para su aprovechamiento tanto en las poblaciones naturales como en su cultivo.

Estación No. 3

Ensayo de Cinco Esquemas de Muestreo Aplicados al Inventario de "Datilillo" y "Cardón".
Ing. Miguel Ruiz Altamirano, Coordinador - Nal. del Proyecto, Evaluación de Recusos - Ftls. - INIF.

Las regiones áridas de México presentan asociaciones vegetales que contienen - gran cantidad de especies útiles. Las condiciones desfavorables de estas zonas re-- quieren urgentemente la incorporación de - este tipo de especies a la actividad económica, con objeto de mejorar los ingresos de algunos núcleos campesinos. Para lograr un aprovechamiento sostenido de la vegetación desértica será necesario su manejo adecuado y éste, a su vez, deberá fundamentarse en el inventario de este recurso.

El desarrollo de este trabajo se originó en la necesidad de derivar esquemas - de muestreo, de aplicación al inventario - de especies útiles del desierto que, ade-- más de proporcionar información confiable, no requieran de fuertes erogaciones.

Para este propósito se compararon cinco esquemas muestrales contra un testigo, en relación a la precisión de los datos obtenidos para algunas variables y el tiempo y costo de la implantación de los primeros. Las especies seleccionadas fueron el Datilillo y el Cardón, por razones de índole - práctica y económica, y la zona de estudio de 400 ha. se eligió parcialmente integrada al C.E.F. "Todos Santos" por presentar condiciones fisiográficas variadas y tener muy cerca las instalaciones del Campo Experimental.

Las esquemas muestrales tienen 1.0% - (A, B y C) y 1.8% (C y E) de intensidad de muestreo; presentando sitios circulares de 0.1 ha., distribuídos en conglomerados (A, B y D) o líneas (C y E). El testigo con-- tiene 400 sitios (10.0% de intensidad de - muestreo) idénticos a los de los esquemas, dispuestos en conglomerados en forma espiral; el tamaño de la muestra fué proporcional al tamaño de los estratos.

Para referir la muestra a diferentes condiciones del área de estudio, se elaboró un plano a escala 1:5000 con 15 estra-- tos fisiográficos diferentes.

De las unidades muestrales se derivó información sobre las variables, número de individuos, altura y diámetro, número de - ramas y brotes (cardón), longitud y diámetro de rosetas (datilillo) y número de renuevos. También se registraron los tiem-- pos de levantamiento de sitios, caminamiento entre sitios y caminamiento entre conglomerados y líneas.

El procesamiento y análisis de la información anterior proporcionó resultados en relación a la precisión de tres variables para las dos especies y los tiempos y costos empleados en la aplicación de cada esquema de muestreo y testigo, concluyéndose que no existe diferencia significativa en la precisión de la información de los esquemas con la del testigo; en cambio, en cuanto al costo, el esquema más barato resultó ser el A, por tener menor cantidad de sitios y caminamientos más cortos.

Estación No. 4

Caracterización y Localización Ecológica de las Poblaciones Silvestres de Jojoba (Simmondsia Chinensis), en el Estado de Baja California Sur.
Q.B.P. Francisco Piña Puente
Biol. Francisco Perez Octavo

El presente trabajo tiene como principal objetivo establecer cuáles son las especies asociadas a las poblaciones silvestres de jojoba (Simmondsia Chinensis), tomando en consideración las condiciones abióticas y bióticas que prevalecen en cada uno de los sitios muestreados, teniendo éstos un área de (50 x 50), que presentan una mayor homogeneidad y heterogeneidad de la comunidad vegetal, también su exposición, pendiente, altura sobre el nivel del mar, su perfil del suelo con su análisis correspondiente.

Los resultados obtenidos dan 21 sitios distribuídos a los largo del estado de B.C. Sur, fueron 14 las especies más asociadas de las 83 reportadas en este trabajo, en cuanto a las condiciones ecológicas predominantes es matorral xerófilo, el análisis de suelo presentó pocas variantes de pH 6.84 - 8.94 su textura es migajón arenoso, areno migajón y arena, con bajo porcentaje de materia orgánica, de nitrógeno, fósforo y un alto porcentaje de potasio en algunos sitios; estas diferencias pueden ser producidas por las condiciones topográficas u origen de los suelos.

Por otro lado se observa que la cobertura no presentaba diferencias entre machos y hembras encontrándose en una proporción 1:1.

Estación No. 5

Ensayos de Métodos de Establecimiento y Reproducción de Jojoba.
Ing. Gustavo Sandoval Chavez

Se discutirá en cuanto a establecimiento de plantaciones de jojoba por semillados circunstancias:

a) Bajo riego.
b) Bajo temporal.

Se considera para el primer caso 3 modalidades que desde el punto de vista de establecimiento de la plantación son satisfactorias para lograrlo y cuya elección haría el agricultor más bien con base a costos de cada modalidad que en base a cuestiones inherentes al desarrolo de la planta. Estas son:

1) Producción de plantas en envase.
2) Siembra directa.
3) Transplante de plántulas a raíz desnuda.

Características de cada una de estas modalidades son:

1) Producción de plantas en envase: quizás la más comúnmente conocida y usada. Desde el punto de vista costos vienen proporcionados por los siguientes conceptos: envase, llenados de envase, sombreado, acarreo, apertura de pozos, eliminación del envase.

2) Siembra directa: Modalidad apoyada por muchas personas debido a que permite eliminar los gastos por mantención en vivero, que en general siempre son elevados. Además, la planta sufriría por maltrato en el manejo, que es común que ocurra utilizando la modalidad de envase. Desventajas que tendría, sería que la superficie definitiva tardaría unos 6 meses a más tardar en tener plantas del desarrollo que tendrían las producidas en vivero.

Por el otro lado implicaría utilizar una cantidad de semilla elevada en comparación con la que se necesitaría en vivero, lo cual es limitante si hay escasez de semilla.

3) Transplante de plántulas: Modalidad intermedia entre las otras dos, que implica el obtener plántulas en un cama de germinación que al alcanzar la plántula cierto desarrollo se planta en su lugar definitivo, lo que ocurre aproximadamente a los 15 días.

Ventajas sobre los otros métodos serían: No ocupa tanta superficie como un vivero, y se reducirían costos por manejo y acarreo de envases; se tienen plantas

seleccionadas por vigor en poco tiempo, menor cantidad de semilla usada que en siembra directa.

Como desventaja tendría una elevada necesidad de mano de obra al transplante, aunque ésta sería a lo mucho equivalente a la del transplante de envases.

Para la modalidad de temporal se considera que es una etapa básica, tanto para plantaciones como para reforestaciones la fase inicial de establecimiento de plántulas, considerándose que es muy poco lo que se ha estudiado al respecto. Se considera también que por varias razones el uso de siembra directa y de transplante de plántulas es poco satisfactorio en cuanto a porcentaje de sobrevivencia. Se discutirán algunas experiencias obtenidas en el uso de tipos y tamaños de envase.

Estación No. 6

Prueba de Ecotipos de Jojoba.
Biol. Jorge I. Sepúlveda B.

Con la finalidad de observar el comportamiento de tres diferentes ecotipos de Jojoba (Simmondsia Chinensis), y correlacionarlas con la producción de cada una de ellas, se realizó un experimento en el Campo Experimental Forestal "Todos Santos", dependiente del C.I.F.N.O., a continuación se describe el mismo.

El experimento está situado en el área del Campo Experimental Forestal Todos Santos, B.C.S.

2. I Metodología
2.II Preparación del terreno

La preparación del terreno consistió en el desmonte y limpia del área, posteriormente a èsta labor se aplicó una nivelación al terreno seguida de un disco cruzado. La formación de los surcos fué manual teniendo éstos una separación de 3 mts. entre sí. Las distancias entre plantas fue de 1.5 mts. y se aplicó una lámina de riego de 10 cm., para la separación del transplante, el cual consistía en la separación de la planta en la cepa previamente preparada.

El diseño experimental consistió en bloques al azar con tres repeticiones. Los ecotipos probados fueron: JAAZ, El Palmar y Gaspareño.

Los tratamiento fueron: Plantas de progenitores no seleccionados, plantas de progenitores seleccionados, cobertura, altura y producción.

Estación No. 7

Módulo de Uso Múltiple de los Recursos Forestales de Zonas Aridas.
Biol. Jorge I. Sepúlveda B.

La necesidad cada vez creciente de productos derivados de los recursos forestales, requiere la búsqueda de alternativas viables para satisfacer las demandas actuales y futuras de una población cada vez mayor.

Las zonas áridas y semiáridas del noroeste de México, poseen una gama de especies vegetales con características de importancia económica, y por tal motivo el módulo que se describe a continuación tiene como objetivo presentar una colección de dichas especies así como, algunos otros elementos que se han integrado para ejemplificar las posibilidades que ofrece el desierto para el hombre.

El módulo con una superficie de 5,000 M2 se localiza en el área del Campo Experimental Forestal "Todos Santos". Como primera fase de la utilización de especies se encuentra un "cerco vivo" compuesto básicamente de Pithaya dulce (Lemairocereus thurberi), Yuca (Yucca valida), Agave (Agave sp.) y Viznaga (Ferocactus sp.).

Del fruto de la pithaya dulce se elaboran jaleas, mermeladas con gran aceptación regional; el fruto de la Yuca contiene Zarzadiosgenina para la producción de esteroides de gran demanda en la farmacopea, sus hojas producen fibra; el agave posee una fibra de buena calidad; de la viznaga se utilizan sus frutos y pulpa para elaborar dulces y conservas.

Dentro de lo que es el módulo propiamente dicho, se encuentra una colección de especies tales como: la Jojoba (Simmondsia chinensis) cuyos usos usos son ampliamente conocidos; la Damiana (Turnera diffusa) empleada en la elaboración de té y licores; el Orégano (Lippia palmeri) utilizada como condimento, el chilpitín (Capsicum sp.) como saborizante.

El módulo por otra parte, cuenta con un potrero para el mantenimiento de algunas cabezas de ganado bovino y Caprino, para tal efecto se establecen algunas leguminosas nativas del género acacia, así como también algunos pastos tales como Buffel (Cenchrus ciliare) y Panizoazul (Panicum antidotale) y arbustos forrajeros como atriplex (Atriplex halimus); Nopal forrajero (Opuntia Ficus indica var. Chapingo).

Los granos derivados de estas especies se probarán como alimentación para conejos y gallinas.

El módulo cuenta con un trabajo experimental sobre extracción de agua de algunas cactáceas por medio de destiladores solares; para consumo humano o para la utilización en el riego de algunos frutales.

El módulo se complementa con algunas especies ornamentales nativas para su utilización en la dasonomía urbana actual y futura en zonas áridas y semiáridas.

Finalmente se trasladará a los participantes a la Playa de San Pedrito donde la Subsecretaría Forestal y de la Fauna ofrecerá una comida preparada con alimentos del desierto y del mar según algunos resultados de investigaciones del C.I.F.N.O.

Establecimiento de Ensayo de Eucalyptus Sp. Para su Adaptación en Zonas Aridas de México[1]

Ing. Oscar Castro Verduzco.[2]

Resumen.- En 1974 se estableció ensayo de introducción de especies de Eucalyptus spp. para su adaptación en en zonas áridas, se probaron 21 especies, observándose - hasta la fecha % de supervivencia en: Camaldulensis 10531 con 50%, y E. viminalis con 0%.

INTRODUCCION

En las regiones áridas y semi-áridas del país, en donde la producción maderable es -- practicamente nula y en el mejor de los casos se restringe el aprovechamiento de unas cuantas especies con valor económico, es de gran importancia determinar técnicas y metodologías que permitan incrementar su economía, la que en la actualidad es básicamente subsistencia.

Los trabajos de reforestación artificial que a la fecha se han llevado a cabo en las - zonas áridas de México son aislados y de pequeña magnitud, en la mayoría de los casos no se han tomado en cuenta factores de vital importancia para lograr el éxito, tales como : Climatología, edafología, corrección de torrentes, conservación de suelos, determinación de las especies más adaptables y productivas; todo ésto motivado fundamentalmente - por escasos medios económicos ausencia de investigación planeada.

El Instituto Nacional de Investigaciones Forestales, a través del Centro de Investigaciones Forestales del Noroeste y su Campo Experimental Forestal "Todos Santos", localizado en el estado de Baja California Sur, ha encaminado líneas de aprovechamiento de especies forestales maderables, tanto nativas como introducidas.

DESCRIPCION DEL AREA DE ESTUDIO.

El área de estudio se localiza en el extremo Septentrional del estado de Baja California Sur, a 84 Km al Sureste de la ciudad de La Paz, y a 5 Km de la población de Todos Santos, el clima dominante de esta área es - cálido, con lluvias de verano BW(h') W (x') (e) con una precipitación pluvial de 181.1 - mm al año, una temperatura media anual de - 22-1ºC. y la presencia de hasta 11 meses de sequía, la temperatura máxima absoluta es de 29.4ºC. con una máxima extrema de 11.7ºC. la evaporación es de 1738.9 mm y la humedad relativa varía de 65 a 80% siendo más húmedos los meses de Junio y Agosto.

Los suelos de esta área son profundos, de textura granular, de consistencia friable, - de color café oscuro con drenaje interno medio y en pH de 7.4 son suelos ricos en carbonato de calcio y potasio pero deficientes en vitrógeno y fósforo.

La vegetación original de esta área fué el matorral Sarcocaulescente, que se caracteriza por la predominancia de las siguientes especies: Pachycereus pringlei, Lemairocereus thurberi, Cyrtorcarpa edulis, Bursera microphyllum, Opuntia cholla y Jatropha cinerea.

Metodología empleada para el establecimiento de ensayo introducción de especies de Eucalyptus spp. en el Campo Experimental Forestal "Todos Santos", a partir de 1974.

Las semillas del género Eucalyptus utilizadas en el experimento, fué proporcionada - por el Departamento de Germoplasma Forestal - del Instituto Nacional de Investigaciones Forestales en el año de 1973. La siembra se -- efectuó en camas de germinación del vivero --

[1]Papel presentado en la Primera Reunión - de Inventarios de Recursos de Tierras Aridas. (La Paz, B.C.S., México.Noviembre 30-Diciembre 6,1980).

[2]Investigador del Centro de Investigaciones Forestales del Noroeste.INIF-SFF-SARH.

del Campo, en Abril del mismo año.

El sustrato consistió en un suelo de textura arenoso el cual fué tratado previamente con formol al 40%, los riegos se aplicaron diariamente posteriormente a la germinación, y una vez que las diferentes especies alcanzaron una altura entre 5 y 10 Cms fueron transplantadas a envases de poliétileno negro protegidas por la media sombra del vivero, permaneciendo en dicha condición hasta Julio de 1974, fecha de su establecimiento en el lote de experimento definitivo.

La preparación del lote experimental consistió en desmonte, limpia y rastro. El transplante se efectúo en la fecha anteriormente mencionada, en el cual se inició el período de lluvias en la localidad.

El diseño experimental fue de bloques al azar con 3 repeticiones.

AVANCE

A 6 años de establecido este experimento, totalmente temporal podemos constatar que los porcentajes de supervivencia en su mayor parte son bajos; no obstante las especies con mayor porcentaje son: *Eucalyptus camaldulensis* 10531, *E. citriodora* 10268 y *E. leucoxylum* 9598 con 50, 41 y 31.6% respectivamente.

Las especies que mostraron un (10%) de su-pervivencia fueron *E. saligna* 7730, *E. viminalis* 9986, *E. saligna* 7810, *E. tereticornis*.

ABSTRACT

An experiment was carried out in 1974 to introduce some species of Eucalyptus spp. into arid zones, and to test their ability to adapt. Twenty one species were tested; up to now, the percentage of survival observed has been 50% in *E. camaldulensis* 10531, and 0% in *E. viminalis*.

Diagnóstico Ecológico de Poblaciones de Jojoba (Simmondsia chinensis) en el Campo Experimental Forestal "Todos Santos", B.C.S.[1]

G.T.F. Salvador Fonseca Vera.[2]

Resumen.- El presente trabajo determina: Fisiografía, exposición, relieve, tipo de suelo, y vegetación asociada con Jojoba en su habitat natural, mediante muestreo de 32 sitios, partiendo de un punto fijo; para conocer en cual se desarrolla mejor.

INTRODUCCION

En el presente trabajo, se estableció un muestreo considerando todas las variables presentadas en el área de estudio como son la fisiografía, exposición, relieve, tipo de suelo y vegetación asociada.

Los sitios se ubicaron de la siguiente manera: Se buscó un punto que reuniera todas las características diferentes posibles, este sitio fué ubicado en la punta del cerro de La Capilla, partiendo de ese sitio con respecto a la orientación de los puntos cardinales se establecieron los sitios de muestreo donde se realizaron tomas de datos.

Esta toma de datos se realizó en 32 sitios de muestreo de los cuales en 12 de éllos, se detectó la presencia de Jojoba (Simmondsia chinensis) y de éstos la mayor parte en el elemento fisiográfico, planicie y ladera con respecto a la exposición, se detecta claramente en la totalidad de los sitios donde se encontró Jojoba, se encuentran expuestos a los vientos predominantes del Noroeste.

El análisis físico-químico comparativo de las muestras de suelo obtenidas de los sitios, se aprecia que hay una predominancia grupo textural areno-limoso con respecto al pH, se observan entre 7.5 a 8.1

De acuerdo a los datos obtenidos, se infiere que factores como suelos y exposición, fueron las características más importantes en la distribución de la Jojoba en el área de estudio; por otra parte, se evidencía la necesidad de profundizar los estudios ecológicos, para las condiciones preferentes que sigue la Jojoba en su habitat y considerarlos como elementos básicos del conocimiento sobre la especie a fín de normar los criterios para su aprovechamiento tanto en las poblaciones naturales como en su cultivo.

ABSTRACT

This paper determines the physiography, exposure, topography, type of soil, and vegetation associated with Jojoba (Simmondsia chinensis) in its natural habitat, through a sampling of 32 different locations, to find out which location is the most suitable for its development.

[1] Papel presentadoen la Primera Reunión de Inventarios de Recursos de Tierras Aridas. (La Paz, B.C.S., México. Noviembre 30-Diciembre 6, 1980).

[2] Investigador del Centro de Investigaciones Forestales del Noroeste. INIF-SFF-SARH.

Ensayos de Métodos de Establecimiento y Reproducción de Jojoba[1]

Ing. Gustavo Sandoval Chávez[2]

Resumen.-Se realizan estudios para determinar la mejor metodología para el establecimiento de plantaciones de Jojoba (Simmondsia chinensis) mediante ensayo de plantas derivadas de semillas ó de reproducción vegetativa; utilizándose diferentes tipos de sustratos, envases y profundidad de siembra.

INTRODUCCION

Entre las diversas etapas por las que atraviesa el cultivo de plantas perennes es de primordial importancia la fase de establecimiento, el cual dependiendo del tipo de planta ó de la parte de interés de ella, puede lograrse de distintas maneras, figurando en primer lugar, el uso de plantas derivadas de semilla ó de reproducción vegetativa y las modalidades específicas que tiene cada una de estas formas.

En el caso de la Jojoba, a pesar de que ya se llevan estudios avanzados se considera que aún falta definir las metodologías más adecuadas para establecer plantaciones comerciales, existiendo controversia.

En el Campo Experimental Forestal "Todos Santos", se vienen realizando ensayos de establecimiento y plantaciones de Jojoba. Este se puede lograr mediante siembra directa ó mediante plantas producidas en vivero ó por transplante de plántulas a raiz desnuda para el caso de contar con riego, ya que para temporal se considera mejor el empleo de plantas en envase.

Para cada una de estas modalidades, hay ciertos aspectos específicos sobre los cuales existen trabajos ya realizados, otros que están en marcha y otros que próximamente se establecerán.

[1] Papel presentado en la Primera Reunión de Inventarios de Recursos de Tierras Aridas. (La Paz, B.C.S., México, Noviembre 30-Diciembre 6,1980).

[2] Investigador del Centro de Investigaciones Forestales del Noroeste. INIF-SFF-SARH.

Entre ellos se encuentran:

Ensayo de profundidad de siembra en condiciones de vivero.

Realizado por el Biólogo Jorge I. Sepúlveda B. e Ing. Heriberto Parra Hake, determinándose que la mejor profundidad en cuanto a la velocidad del desarrollo de la planta fué de 2 cms.

- Ensayo de profundidad, intervalo de riego e intervalo de siembra directa. Experimento que está en marcha y en el cual se busca determinar cual profundidad es más adecuada para siembra directa, ensayándose 2, 4 y 6 cm, y aunque se dice que esta última es muy profunda en base a experiencias anteriores, se busca determinar las interaciones con el intervalo de riego, factor con el que no se había trabajado anteriormente.

Además se busca determinar cual es la cantidad de semilla por sitio, entendiéndose éste, como el lugar con el que debe haber 3 plantas número adecuado para que por lo menos una sea femenina. El experimento es un ensayo factorial en cuadro latino, con tres factores a tres niveles.

- Transplante de plántulas a raiz desnuda: plantas producidas en semillero con sustrato de arena fueron transplantadas a raiz desnuda en surco, obteniéndose buena sobrevivencia faltando por definir el intervalo óptimo de riego.

- Ensayo de tipos de envase para temporal. En desarrollo en el Campo Experimental Forestal, se están usando envases de polietileno de 8 cm de diámetro x 16 de longitud --

con una planta, y envases de poliétileno de 12 x 20 y latas de cerveza ó jugo, además con y sin cubierta de poliétileno transparente y en el caso de los envases de poliétileno la eliminación del envase, dejando únicamente el cepellón contra la conservación del envase. En el caso de las latas, el transplante se realizó con todo y lata.

Se busca cual de éstas formas puede ser más adecuada para asegurar la sobrevivencia de la plántula. El transplante se realiza aún antes de la emergencia, ya que en este caso el envase se le asigna la única función de ser un medio para la germinación conservando la humedad del sustrato en condiciones en que no se cuenta con riego. Por otro lado, se busca que la raiz primaria no sufra daño y profundice lo más posible en busca de agua.

- Establecimiento de una parcela demostrativa en el Ejido La Trinidad. En este se usaron los mismos tipos de envase mencionados anteriormente, pero con plántulas de una edad de 3 semanas a partir de la siembra, por lo cual no se utilizaron cubiertas de poliétileno. Se emplearon además plantas de envase de 2 años de edad, a fin de observar los resultados del empleo de tales plantas.

- Por otro lado, independientemente de cual de los métodos anteriores sea el mejor para el establecimiento, se considera aún más deseable la reproducción vegetativa por las muchas ventajas que reporta, para lo cual se han desarrollado trabajos sobre reproducción por estaca.

Al respecto, se han usado diversos tipos de sustratos y aunque no se ha logrado la obtención de buenos resultados, el sustrato que parece ser más prometedor es una mezcla de peat-moss con perlita. Los otros ensayados han sido arena y la tierra de envase en la región. El tipo de estaca que ofrece mayores probabilidades es el de tallos tiernos aplicables con la epidermis aún verde, no madura.

ABSTRACT

Studies are being conducted to determine the best method for establishing of Jojoba (Simmondsia chinensis) plantations by means of an assay of plants derived from seeds or from vegetative reproduction, utilizing various types of substrates, vessels, and depth of sowing.

Caracterización y Localización Ecológica de las Poblaciones Silvestres de Jojoba (Simmonsia chinesis) en el Estado de Baja California Sur[1]

Q.B.P. FRANCISCO PIÑA PUENTE[2]
BIOL. FRANCISCO PEREZ OCTAVO

Resumen.-Se realizó estudio de localización y caracterización ecológica de Jojoba (Simmondsia chinensis), tipos de suelos, especies asociadas a las comunidades vegetales en 21 puntos distribuidos en el Estado de B.C.S., atendiendo relacionar un análisis de correlación.

INTRODUCCION

En el presente trabajo se tomó en consideración, las especies más asociadas a las poblaciones silvestres de Jojoba (Simmondsia chinensis), y el criterio que se utilizó para definir las especies, fué por medio de un enlistado y la frecuencia con que ocurren ellas, también se tomaron las condiciones abióticas y bióticas que prevalecen en cada uno de los sitios, en los cuales se realizó principalmente, la delimitación del área (50 X 50 Mts) de los sitios de muestreo, siendo ésta arbitraria, puesto que el área mínima de muestreo varía de un sitio a otro, debido a que en un estudio preliminar se determinó en Todos Santos, B.C.S. ésta, y fué de (32 X 32), ya que en los meses que se realizó fué de sequía; de los cuales se estimaron aquéllos que presentaran una mayor homogeneidad y heterogeneidad de la comunidad vegetal, también su exposición, pendiente, altura sobre el nivel del mar y a cada sitio se le tomo perfil de suelo, con su respectiva muestra que posteriormente fueron analizados.

Como resultado obtuvimos de los 21 sitios distribuidos a lo largo del estado de Baja California Sur, las especies asociadas fueron 14 de las 83 que se reportan en este trabajo, ya que estas se mantuvieron en una misma distribución y se presentaron con mayor frecuencia a lo largo de dicho recorrido, así como en los sitios muestreados, aunque no se deben discriminar a las demás especies, puesto que ellas también juegan un papel muy importante en dichas comunidades vegetales.

Las especies que se han considerado con mayor importancia son:
Machaerocereus gummosus Pitahaya Agria, Pachycereus pringlei Cardón, Opuntia cholla Choya, Jatropha cuniata Matacora, Jatropha cinerea Lomboy, Bursera odorata Torote, Pedilanthus macrocarpus Candelilla, Lycium californicum Frutilla, Lemairocereus thurberii Pitahaya Dulce, Bursera hidsiana Copal, Cytocarpa edulis Ciruelo, Mayternus phylantoides Mangle Dulce.

Esto se fundamenta con el análisis de las condiciones ecológicas presentes y la existente relación con el tipo de vegetación que es el predominante el matorral xerófilo y en cuanto al resultado de los análisis químicos de las muestras del suelo, se contempla que existe una pequeña variación, el pH es más alcalino en Bahía Asunción y Punta Santa Inés y en los demás es de 6.84 a 8.94 de pH, en cuanto a la textura se observó que los más predominantes son: Migajón-arenoso, areno-migajón y arena, con bajo porcentaje de materia orgánica, así como un bajo porcentaje de nitrógeno, fósforo, aunque en algunos sitios es alto el porcentaje de potasio.

Estas diferencias pueden ser producidas por las condiciones topográficas y así como su origen de éstos suelos, aunque se observó

[1]Papel presentado en la Primera Reunión de Inventarios de Recursos de Tierras Aridas. (La Paz,B.C.S., México. Noviembre 30-Diciembre 6,1980).

[2]Investigadores del Centro de Investigaciones Forestales del Noroeste. INIF-SFF-SARH

que casí más del 50% donde se desarrolla Jojoba en los sitios muestreados, principalmente se encuentran creciendo sobre laderas y planicies.

Por otro lado, se observó que la cobertura y la altura no hubo diferencias muy marcadas con respecto machos y hembras, aunque podemos inferir que tienen un vigor aparente, estando esta en una proporción a 1:1.

Se observó una marcada diferencia que en la parte Sur del Estado existe mayor abundancia de Jojoba, pero con menor cobertura, en cambio en la Región Norte del Estado, son número menor individuos por hectárea pero mayor cobertura, ésto se le puede atribuir a las diferencias climáticas que prevalecen en el Sur y el Norte del Estado, así como a los regímenes de precipitación anual en cada una de éstas zonas.

Desde un punto de vista general en los sitios muestreados presentan diferencias ecológicas bien definidas, por lo que es necesario obtener datos acerca de producción de semilla por hectárea, para definir cuales son los sitios más productores y ver cuales son las condiciones más favorables para esta productividad, para que así de esta manera se puedan utilizar éstos datos en el manejo del recurso silvestre y/o domesticación de Jojoba, así como de llevar un mejor estudio fenológico de éstas.

ABSTRACT

A study was carried out in 21 scattered locations in Baja California concerning the ecologic characterization and location of Jojoba (Simmondsia chinensis), the types of soil, and the species common to the plant communities, trying to determine a correlation analysis.

Prueba de Ecotipos de Jojoba[1]

Biól. Jorge I. Sepúlveda B.[2]

Resumen.- El CIFNO, estableció en 1975 experimento de 3 diferentes ecotipos de Jojoba (Simmondsia chinensis) partiendo de plantas seleccionadas y no seleccionadas mediante diseño de bloques al azar, con la finalidad de observar su comportamiento y obtener correlación en cada una de ellas.

INTRODUCCION

Con la finalidad de observar el comportamiento de tres diferentes ecotipos de Jojoba (Simmondsia chinensis), y correlacionarlas con la producción de cada una de ellas, se realizó un experimento en el Campo Experimental Forestal "Todos Santos", dependiente del C.I.F.N.O., a continuación se describe el mismo.

El experimento está situado en el área del Campo Experimental antes citado.

2.1 Metodología

2.11 Preparación del terreno

La preparación del terreno consistió en el desmonte y limpia del área posterior a esta labor, se aplicó una nivelación al terreno seguida de un disque cruzado. La formación de los surcos fué manual teniendo éstos una separación de 3 mts entre sí. Las distancias entre plantas fué de 1.5 mts y se aplicó una lámina de riego de 10 cm, para la separación del transplante, el cual consiste en la colocación de la planta en la cepa previamente preparada.

El diseño experimental consistió en bloques al azar con tres repeticiones. Los ecotipos probados fueron: JAAZ, El Palmar, y Gasapareño.

Los tratamientos fueron:
Plantas de progenitores no seleccionadas.
Plantas de progenitores seleccionadas.
Cobertura.
Altura y producción.

El experimento fué establecido en Agosto de 1975, los datos que a continuación se proporcionan fueron los correspondientes al periodo de producción de 1979. Y representa la primera producción formal de lote obtenido desde su establecimiento.

Debido a la importancia que reviste el factor de producción se ha dado el análisis de los datos previos obtenidos al respecto.

En el cuadro No. 1 , se presentan los promedios de producción por tratamiento.

CUADRO No.1
PROMEDIOS DE PRODUCCION DE SEMILLA DE JOJOBA OBTENIDA EN EL LOTE EXPERIMENTAL 4-1.

SUBLOTE ECOTIPOS	PROMEDIOS PARCIALES. KGS.	PROMEDIOS TOTAL GRUPOS. KGS.
1 JAAZ	.477	.479*
2 PJLA	.482	
3 P	.350	
4 G	.456	.403**

* INDIVIDUOS SELECCIONADOS
** INDIVIDUOS NO SELECCIONADOS.

ABSTRACT

The Northwestern Center for Forestry Research (CIFNO) carried out in 1975 experiments on three different ecotypes of Jojoba (Simmondsia chinensis) utilizing some carefully selected plants, and others selected at random. The purpose of these experiments was to observe their behavior and to obtain correlation in each of the plants.

[1] Papel presentado en la Primera Reunión de Inventarios de Recursos de Tierras Aridas. (La Paz, B.C.S., México, Noviembre 30-Diciembre 6,1980).

[2] Investigador del Centro de Investigaciones Forestales del Noroeste. INIF-SFF-SARH.

Módulo de Uso Múltiple de los Recursos Forestales de Zonas Aridas[1]

Biol. Jorge I. Sepúlveda B.[2]

Resumen.-En el Campo Experimental Forestal "Todos Santos", se ha establecido un Módulo de Uso Multiple de 5,000 M2. para ejemplificar las posibilidades que ofrece el desierto al hombre; así como otros elementos.

INTRODUCCION

La necesidad cada vez creciente de productos derivados de los recursos forestales, requiere la búsqueda de alternativas viables para satisfacer las demandas actuales y futuras de una población cada vez mayor.

Las zonas áridas y semi-áridas del noroeste de México, posee una gama de especies vegetales con características de importancia económica por tal motivo el módulo que se describe a continuación tiene como objetivo presentar una colección de dichas especies así como, algunas otros elementos que se han integrado para ejemplificar las posibilidades que ofrece el desierto para el hombre.

El módulo con una superficie de 5,000 M2 se localiza en el área del Campo Experimental Forestal "Todos Santos", como primera fase de utilización de especies se encuentra un "cerco vivo" compuesto básicamente de pitahaya dulce (Lemairocereus thurberi), Yuca (Yucca valida) Agave, (Agave s.p.), biznaga (Ferocactus s.p.)

Del fruto de la pitahaya dulce se elaboran jaleas, mermeladas con gran aceptación regional; el fruto de la Yuca contiene Zarzodiosgenina para la producción de esteroides de gran demanda en la farmacopea , sus hojas producen fibra; el agave posee una fibra de buena calidad, la biznaga se utiliza sus frutos para elaborar dulces y conservas.

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[2] Investigador del Centro de Investigaciones Forestales del Noroeste.INIF.SFF-SARH.

Dentro de lo que es el módulo propiamente dicho, se encuentra una colección de especies tales como: La Jojoba (Simmondsia chinensis) cuyos usos son ampliamente conocidos; la Damiana (Turnera diffusa) empleada en la elaboración de té y licor; el Orégano (Lippia palmeri)utilizándose como condimento; el Chilpitín (Capsicum s.p.) como saborizante.

El módulo por otra parte, cuenta con un potrero para el mantenimiento de algunas cabezas de ganado Bovino y Caprino, para tal efecto se establecen algunas leguminosas nativas del género acacia, así como también algunos pastos tales como Buffel (Cenchrus ciliare) y Panizoazul (Panicum antidotale) y arbustos forrajeros como Atriplex (Atriplex halimus); Nopal forrajero (Opuntia Ficus indica var. Chapingo).

Los granos derivados de estas especies se probarán como alimentación para conejos y gallinas.

El módulo cuenta con un trabajo experimental sobre extracción de agua de algunas cactaceas por medio de destiladores solares; para consumo humano o para su utilización en el riego de algunos frutales.

El módulo se complementa con algunas especies ornamentales nativas para su utilización en la dasonomía urbana actual y futura en zonas áridas y semi-áridas.

ABSTRACT

A multiple use model has been established on 5000 square meters in the "Todos Santos" Experimental Forest to demonstrate the possibilities the desert offers man.

Objetivos de la Investigación en el Centro de Investigaciones Forestales Del Noroeste (C.I.F.N.O.)[1]

Biól. Jorge I. Sepúlveda B.[2]

Resumen.- Se presentan los diversos proyectos de investigación del CIFNO: Proyecto Uso Múltiple de los Recursos Forestales no Maderables con 3 subproyectos; proyecto Protección Forestal con 2 subproyectos; proyecto Evaluación del Recurso Forestal; proyecto Establecimiento y Manejo de Plantaciones Comerciales; exponiéndose sus objetivos.

INTRODUCCION

A partir de su creación, el Centro de Investigaciones Forestales del Noroeste, ha priorizado sus proyectos de investigación y experimentación, de tal manera, que los resultados derivados de éstos, aporten soluciones viables a la problemática forestal de la región de México, para tal fín, cuenta con los siguiente proyectos de investigación:

1.-PROYECTO DE USO MULTIPLE DE RECURSOS FORESTALES NO MADERABLES.

Este proyecto cuenta con tres subproyectos denominados:

1.- Subproyecto Catálogo de Especies Utiles
Los objetivos del subproyecto son la detección en el área de influencia del CIFNO, de las especies cuyas propiedades representan un interés económico en las diferentes actividades humanas. Asimismo, el subproyecto realiza todos los estudios de investigación básicos para la determinación de los principios activos de estas especies. Actualmente se ha incluído el Catálogo de Especies Utiles, correspondiente al estado de Baja California Sur.

2.- Subproyecto Manejo de Especies en su Estado Natural.
El subproyecto está dirigido hacia la determinación de técnicas y metodologías de manejo de las especies que, dadas sus características de abundancia, puedan ser utilizadas en su habitat natural.

Dentro de las especies que actualmente investiga este Centro, se encuentran: La Jojoba (_Simmondsia chinensis_); Orégano (_Lippia palmeri_); Damiana (_Turnera diffusa_); Yuca (_Yucca spp_)
A la fecha estos trabajos se realizan en el Campo Experimental Forestal "Todos Santos", B.C.S. y la Residencia de Ensenada, B.C.

3.- Subproyecto Domesticación y Aprovechamiento de Especies Utiles.

Dadas las características de aridez de la región Noroeste de México y previendo una disminución gradual de agua disponible, así como su calidad, día a día más baja, debido a la infiltración marina, es de vital importancia la búsqueda de especies que en un futuro ofrezcan las alternativas necesarias para la introducción de especies nativas como nuevos cultivos adaptables a esas condiciones.

Es así que, este subproyecto, tiene como objetivo determinar las técnicas que permitan la inducción al cultivo de dichas especies. Destacan actualmente por su importancia económica: Jojoba (Simmondsia chinensis), Damiana (_Turnera diffusa_), Orégano (_Lippia palmeri_), así como algunas forrajeras nativas. Los trabajos se realizan en el C.E.F. "Todos Santos", B.C.S., y en la Residencia de Ensenada, B.C.

II.- PROYECTO PROTECCION FORESTAL.

El proyecto cuenta con dos subproyectos que a continuación se describen:

1.-Subproyecto Sanidad Forestal

Abocado a la determinación de plagas y en-

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fermedades que afectan las especies con las que se está trabajando; así mismo estudia los métodos de control de las mismas.

2.- Subproyecto Especies Amenazadas.

Este subproyecto determina mediante estudios de localización las especies que de - una u otra forma se encuentran amenazadas y - realiza, los estudios pertinentes para determinar cuales son las causas que orillan a una especie a estar en peligro de extinción. En - este subproyecto tienen relevancia los estu - dios ecológicos sobre Pinus atenuatta en la - sierra de Ulloa, B.C. y diversas especies como el Cirio (Idria columnaris)y de algunos - agaves.

III.- PROYECTO EVALUACION DE RECURSO FORESTAL

Los ecosistemas desérticos representan - un equilibrio delicado en cuanto a la composición de sus elementos vegetales. Si el interés de una u otra especie se dirige a su explota - ción, es necesario contar con los elementos - técnicos que determinen cuanto hay del recurso a aprovechar y hasta donde este aprovechamiento no atente con la supervivencia de la espe - cie. Es por eso en forma concreta, que el proyecto tiene como objetivos determinar las técnicas más adecuadas para conocer como, cuándo y hasta donde es posible aprovechar una espe - cie. Dentro de este proyecto destacan los estudios realizados en Yuca (Yucca valida) y Car - dón (Pachycereus pringlei)y Jojoba (Simmondsia chinensis)

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IV.- PROYECTO ESTABLECIMIENTO Y MANEJO DE PLANTACIONES COMERCIALES.

El proyecto tiene como objetivo el estudio de especies forestales no maderables y maderables para su utilización en las diferentes ramas de la industria. Para este fín determina, los métodos de reproducción y de establecimiento más adecuados de estas plantaciones. Estu - dia así mismo la fenología de las especies y - cuenta con un banco de germoplasma forestal, en la que se desarrollan las técnicas necesa - rias para la propagación del material existente.

Dentro de los estudios que sobresalen en el proyecto, se encuentran los ensayos con especies nativas de pinus en la sierra de Juárez y Ulloa, en B.C. asi como la sierra de La Laguna y Campo Experimental Forestal "Todos Santos, Baja California Sur.

ABSTRACT

This paper describes various research projects at CIFNO (Northwestern Center for Forestry Research), explaining their objectives. They include the multiple utilization project of the non-timber forestry resources, including three sub-projects: forestry protection, including two sub-projects; the evaluation of forestry resources project; and establishment and management of commercial plantations.

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